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CRITICAL REVIEW OF THE USE OF BIOCONCENTRATION FACTORS FOR HAZARD CLASSIFICATION OF METALS AND METAL COMPOUNDS

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TABLE OF CONTENTS

Page

EXEC	UTIVE SUMMARY	iv
1.	INTRODUCTION	1
2.	 2.1 METAL ESSE 2.2 HOMEOSTAT 2.2.1 Cadmin 2.2.2 Copper 2.2.3 Lead 2.2.4 Nickel 2.2.5 Silver 2.2.6 Zinc 	BIOACCUMULATION
	2.3 RELATIONSE 3.3.1 Metal-	IP BETWEEN WATER CONCENTRATIONS AND BCFS10 Specific Examples
	2.4 BIOACCUMU FOR METALS 2.4.1 Relatio	LATION AS AN INDICATOR OF CHRONIC TOXICITY AND METAL COMPOUNDS
	2.5 SECONDARY AND METAL 2.5.1 Metals 2.5.2 Organo	POISONING AND BIOMAGNIFICATION OF METALS COMPOUNDS
3.	CONCLUSIONS	
4.	REFERENCES	

APPENDICES

A DATABASE OF BIOCONCENTRATION FACTORS (BCFs)

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

LIST OF FIGURES

Figure 1 Cadmium BCFs for Fish.14 2 3 Cadmium BCFs for Bivalves.....16 4 5 6 7 8 9 Zinc BCFs for Fish......25 10 11 12 13 Relationship Between BCFs and Exposure Concentrations at the U.S. EPA Chronic 14 15 Relative Acute Sensitivities of Freshwater Organisms to Cadmium35 16 17 18 19 Relative Acute Sensitivities of Freshwater Organisms to Nickel......41 20 Relative Acute Sensitivities of Freshwater Organisms to Silver......42 21 22 23 24

LIST OF TABLES

Table

Page

1	Examples of some essential trace metals and their function.	4
2	Examples of regulatory mechanisms used by aquatic organisms for several metals	
3	Silver BCF data for species with more than one data point	
4	Relationship between lead BCFs and toxicity in the snail Lymnaea palustris	
	(Borgmann et al. 1978).	30

Page

EXECUTIVE SUMMARY

INTRODUCTION

Bioaccumulation potential is currently used in Europe and North America as a criterion for the hazard classification of organics and is proposed for use with metals. Classification of substances is based upon the premise that hazard can be identified using "inherent" properties of the substance. It is known that organisms bioaccumulate and store metals in their tissues to levels higher than those in their aqueous environment since many of the metals are essential to biological functions. Based on this background, an in-depth review of the bioconcentration literature (laboratory tests) was undertaken to address the following questions: (1) do the scientific data support that metals and metal compounds are bioaccumulative and can this determination be made using the properties of the substance?; (2) do bioconcentration factors for metals and metal compounds provide an indication of the potential for long-term effects in aquatic organisms?; and (3) is it appropriate to use bioaccumulation as a hazard assessment tool for metals and metal compounds?

BACKGROUND

In hazard assessment, bioaccumulation potential is typically assessed using bioconcentration factors (BCFs), on the basis that the ratio of the tissue to water concentration of a chemical is predictive of adverse effects and may reflect a concern for trophic transfer of the substance. BCFs are often used in place of bioaccumulation factors (BAFs) because the latter are not typically available. This report demonstrates that metal BCFs for many taxonomic aquatic groups, and fish in particular, are inversely related to the metal concentration in water. As a result, individual BCFs are not indicative of a metal's bioaccumulation potential in these organisms (i.e., large BCFs do not indicate that bioaccumulation potential is higher; they reflect lower exposure concentrations). Other types of organisms are net accumulators of metals (i.e., they are able to store large quantities of metals in detoxified forms). In these organisms, the BCF may be more indicative of bioaccumulation potential because the metal appears to be stored in a detoxified form. As such, bioaccumulation potential of metals and metal compounds, whether measured as a BCF or tissue residue, cannot be directly correlated with hazard.

METAL ESSENTIALITY

It is well known that a variety of metals are essential for various biological functions, such as enzymatic and metabolic reactions. Metal bioaccumulation is an important process whereby aquatic organisms obtain these essential metals. Aquatic biota regulate their internal concentrations of essential metals in three ways: active regulation, storage, or a combination of active regulation and storage. Active regulators are organisms that maintain stable tissue concentrations by excreting metal at rates comparable to the intake rate. Other biota store metals in detoxified forms, such as in inorganic granules or bound to metallothioneins. Some organisms use a combined regulatory strategy. It should also be noted that non-essential metals are often also regulated to varying degrees because the mechanisms for regulating essential metals are not metal-specific.

In general, essential metals such as copper and zinc tend to be actively regulated by organisms such as decapod crustaceans, algae and fish. Conversely, organisms such as bivalve molluscs, barnacles, and aquatic insects tend to store these metals in detoxified forms. Non-essential metals, such as cadmium, are typically stored in detoxified forms and not actively regulated.

April 2000 555-3690-001 (01) \\KIRKLAND_I\VOLI\DATA\working\3690biaaccumulation report2 (march 2000).doc

RELATIONSHIP BETWEEN WATER CONCENTRATIONS AND METAL BCFS

As summarized above, many aquatic organisms regulate metals to varying degrees. Consequently, an inverse relationship between water concentrations of metals and the corresponding BCF is often observed. This is because at low water concentrations organisms are actively accumulating essential metals (and often other metals via the same uptake mechanisms) to meet their metabolic requirements. At higher water concentrations, organisms with active regulatory mechanisms are able to excrete excess metals or limit uptake. As a result, metal concentrations in tissue based on a range of exposure concentrations may be quite similar, but the BCFs will be quite variable (i.e., higher BCFs at lower exposure concentrations and lower BCFs at higher exposure concentrations). Consequently, an individual BCF provides little information on the bioaccumulation potential of a metal.

BIOACCUMULATION AS AN INDICATOR OF CHRONIC TOXICITY FOR METALS

The concept that BCFs can be used as an indicator of long-term or chronic toxicity to aquatic organisms stems from the assumption that larger BCFs are indicative of higher tissue concentrations, which in turn result in direct or secondary poisoning. This concept is primarily relevant to organic chemicals with narcosis as the mode of toxic action. However, this relationship does not apply to all chemicals, including metals. In fact, some studies have shown that accumulated metal (whole body residue) may be poorly, or even negatively, correlated with toxicity. Organisms that tend to bioaccumulate metals to high levels (e.g., bivalves, barnacles) do so because they are able to store the metals in detoxified forms (i.e., in granules, bound to metallothionein). Consequently, the magnitude of a metal's BCF cannot be used as a predictor of chronic toxicity.

SECONDARY POISONING AND BIOMAGNIFICATION OF METALS

Secondary poisoning results when toxicant concentrations in an organism reach a level that is toxic to the organisms that feed on it. Substances that bioaccumulate or biomagnify in food webs often are considered to have the greatest potential to cause secondary poisoning. It has been reported that the classic concept of biomagnification and food chain poisoning, based primarily on chemicals such as DDT and PCBs, does not hold for metals (naturally occurring organo-metals may be an exception). This may be explained in part by the limited bioavailability of the inorganic forms of metals in food and by the regulation of metals that occurs in both aquatic and terrestrial organisms. A limited amount of site-specific data are available suggesting that some inorganic metal compounds may result in secondary poisoning, but further research is needed on this topic. Regardless, the literature clearly shows that BCFs cannot be used to estimate bioaccumulation and biomagnification potential for metals and metal compounds. Hence, they are not useful descriptors of hazard.

CONCLUSIONS

This report concludes that metal BCFs are not indicative of the potential for direct toxicity, that there is limited evidence that inorganic forms of metals result in secondary poisoning, and that inorganic forms of metals do not biomagnify in food webs. Consequently, we conclude that bioaccumulation is not an appropriate parameter for assessing the hazard potential of metals.

April 2000 555-3690-001 (01) WCIRKLAND_IVOLIVDATA vmorking 3690 bioaccumulation report2 (march 2000).doc

1. INTRODUCTION

Hazard identification is a process for determining whether chemical substances should be classified as dangerous to the environment. Formal classification protocols based on hazard identification have been established in Europe and an internationally harmonized system for chemical classification is under development through the Organization for Economic Cooperation and Development (OECD). Chemical substances are classified under these protocols based on their persistence, toxicity, and bioaccumulation potential (e.g., EU 1967, 1991). These protocols were primarily derived for organic chemicals.

Over the past several years, a series of workshops have been held to discuss the applicability of these protocols to metals and metal compounds (e.g., OECD 1995, Canada/EU 1996). Based on the workshops and subsequent discussions, it was concluded that the current use of bioaccumulation data in classifying organic compounds is not appropriate for classifying metals and metal compounds. Reasons for reaching this conclusion include:

- 1.) Unlike organic compounds of anthropogenic origin, metals occur naturally in the environment and many metals are essential nutrients for organisms. As a result, organisms have developed homeostatic processes for regulating internal tissue concentrations of many metals;
- 2.) Due to these homeostatic processes, an inverse relationship is often observed between bioaccumulation and metal exposure. Consequently, use of a single bioconcentration factor (BCF) for hazard classification is not appropriate for metals;
- 3.) Bioaccumulation has been used in hazard classification as a surrogate for chronic toxicity. The premise behind this approach is that highly bioaccumulative chemicals are also more likely to cause sublethal/chronic effects. As discussed in this report, the applicability of this concept is not appropriate for metals and metal compounds; and
- 4.) There is not a clear relationship between bioaccumulation potential and secondary poisoning from metals (e.g., effects via prey ingestion).

The purpose of this report is to provide a detailed review of the scientific literature on each of the above points. The report focuses on the bioaccumulation potential of metals and inorganic metal compounds. Organometallic compounds behave differently in the environment and within organisms. As such, these compounds need to be evaluated separately from a scientific perspective, as well as from a regulatory perspective with regards to hazard classification. In the remainder of this report, the term "metals" refers to metallic elements or inorganic metal compounds (e.g., CdCl₂) unless specified otherwise. This report specifically provides detailed summaries and/or analyses on:

1.) The state-of-the-science regarding bioaccumulation of trace metals in aquatic organisms (e.g., Ag, Cd, Cu, Ni, Pb, Zn);

1

2.) Limitations on the use of BCFs for hazard identification;



- 3.) Appropriate use of bioaccumulation data for metals as an indicator of secondary poisoning (Canada/EU 1996); and
- 4.) Evaluation of biomagnification (increased concentrations at successively higher trophic levels) for metals.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

April 2000 555-3690-001 (01) \KIRKLAND_1\YOL1\DATA\working\3690bioaccumulation report2 (march 2000).doc

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2. REVIEW OF METAL BIOACCUMULATION

Although bioaccumulation data for metals and metal compounds can be an extremely useful tool in various applications when used appropriately, these data are inappropriate for hazard classification of metals and most metal compounds. Metal bioaccumulation is an important process whereby aquatic organisms acquire essential elements for key metabolic processes. The essentiality of certain metals has led organisms to develop strategies for actively regulating and/or sequestering metals in detoxified forms. Consequently, bioaccumulation potential, and the parameters typically used to estimate it (e.g., BCFs), should not be interpreted for metals in the same manner as for synthetic organic compounds. The more important issue, as Beyer (1986) pointed out, is that overemphasizing bioaccumulation or biomagnification potential often diverts from the more important question of whether metal concentrations in the environment are toxic to humans, wildlife, or aquatic life.

The following first provides a brief overview of the strategies used by aquatic biota to regulate both essential and non-essential metals. Bioconcentration factors for a variety of metals and aquatic organisms are then graphically presented to demonstrate the difficulties in interpreting a single BCF. Finally, a review of the scientific literature is presented to provide a summary of available information on metal bioaccumulation and to evaluate the potential to use bioaccumulation data as an indicator of direct toxicity or toxicity via secondary poisoning.

2.1 METAL ESSENTIALITY

It is well demonstrated that a number of metals are essential for various biological functions and are critical in many of the enzymatic and metabolic reactions occurring within an organism. Several metals (e.g., sodium, potassium, magnesium, and calcium) occur in large concentrations in organisms. A second set of metals, termed trace metals, occur at much lower concentrations (normally <0.01%) in organisms (Simkiss and Taylor 1989, Venugopal and Luckey 1974). Trace metals can generally be categorized into essential and non-essential groups. Simply defined, essential metals are those necessary for tissue metabolism and growth (Leland and Kuwabara 1985). Essential trace metals and some of the roles they play in organism metabolism and growth are summarized in Table 1. Note that not all of these metals are known to be essential to aquatic biota. For example, chromium is known to be essential to terrestrial vertebrates, but no references were found which identified chromium as essential to aquatic life.

Other trace metals, such as cadmium, lead, mercury and silver, are generally considered nonessential. However, these metals also appear to be regulated to varying degrees because the mechanisms for regulating essential metals (described below) are not metal-specific (Phillips and Rainbow 1989).

3

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

Table 1. Examples of some essential trace metals and their function.

Metal	Example of function
Chromium	Cofactor for insulin action
Cobalt	Component of vitamin B ₁₂
Copper	Prosthetic group of cytochrome and hemocyanin
Iron	Prosthetic group of hemoglobin
Manganese	Cofactor of arginase
Molybdenum	Cofactor of xanthine oxidase
Nickel	Cofactor of urease
Selenium	Cofactor of glutathione peroxidase
Zinc	Carbonic anhydrase, carboxy-peptidase A and B

From: Depledge and Rainbow (1990), Parametrix (1995), and Goyer (1996).

2.2 HOMEOSTATIC CONTROL OF METALS

Given the number and importance of trace metals to aquatic life, organisms have developed a variety of homeostatic control mechanisms to regulate their concentrations *in vivo*. The mechanisms by which metal concentrations are regulated vary widely between organisms (George et al. 1980, Mason and Nott 1981, Rainbow et al. 1980, Simkiss 1981, White and Rainbow 1984, Rainbow 1988, Viarengo 1989, Depledge and Rainbow 1990) and, as such, aquatic organisms are generally classified as regulators, partial regulators, or non-regulators (Phillips and Rainbow 1989). These terms are somewhat of a misnomer as all organisms regulate metals – it is the mechanisms by which they do so that distinguishes them. Consequently, we have renamed these categories to more accurately describe the mechanisms by which metals are regulated.

<u>Active Regulation</u>: Active regulators are organisms that maintain stable tissue concentrations by excreting metal at rates comparable to the intake rate. Some decapod crustaceans, for example, regulate zinc and copper using this mechanism (Rainbow 1988).

<u>Active Regulation/Storage</u>: Organisms in this group control internal metal concentrations through a combination of active regulation and storage. Trace metals are usually stored in the form of metallothioneins and occasionally as granules at high ambient concentrations (Phillips and Rainbow 1989). Storage is normally in the hepatopancreas and kidney. Metals stored in this fashion are generally metabolically available. Fish and many invertebrates use this combined strategy of regulation and storage.

<u>Storage</u>: Some organisms store large concentrations of metals in a detoxified, normally granular, form. Storage location varies by metal and by species (Phillips and Rainbow 1989). For any given species, organisms may exclusively use storage for one metal while using an active regulation/storage strategy for a different metal. Additionally, some bivalve molluscs use both metallothionein and granular storage mechanisms for detoxification. Metal and species-specific examples of granular storage include zinc for barnacles (Rainbow 1987) and copper for oysters (Brown 1982).

4

The following provides a review, by metal, of the regulatory strategies used by different aquatic biota. Most research on this topic has focused on cadmium, copper, and zinc. As a result, most of the examples provided below are based on these metals. Where available, examples of regulatory strategies are also provided for other metals. It should be noted that the regulatory mechanisms used by aquatic biota to regulate metals do not always fall into the three discrete categories defined above, but fall along a gradient of strategies (Rainbow et al. 1990). A summary of the mechanisms used by different biota for various metals is provided in Table 2.

Metal	Active Regulation	Active Regulation/Storage	Storage
Cadmium			
Bivalves			Х
Gastropods			
Annelids		x	
Insects			Х
Amphipods			
Decapods		x	Х
Barnacles			Х
Fish		X	
Copper			
Bivalves			Х
Gastropods			X
Annelids		X	
Insects			Х
Amphipods		x	Х
Decapods	Х	х	
Barnacles			Х
Fish	х		
Lead			
Bivalves			х
Gastropods			X
Annelids		х	
Insects			х
Amphipods			x
Decapods		х	Х
Barnacles			x
Fish		х	
Nickel			
Bivalves			
Gastropods			
Annelids			
Insects			
Amphipods			
Decapods			
Barnacles			
Fish			
Silver			
Bivalves			
Gastropods			x

Table 2.	Examples of regulatory	y mechanisms used by aquatic organisms for	r several metals.

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April 2000 55-3690-001 (01) \KIRKLAND_I\VOLI\DATA\morking\3690bioaccumulation report2 (march 2000).doc

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		Active		
Metal	Active Regulation	Regulation/Storage	Storage	
Annelids			X	
Insects				
Amphipods				
Decapods				
Barnacles				
Fish				
Zinc				
Bivalves		х	Х	
Gastropods		Х	Х	
Annelids	х			
Insects			Х	
Amphipods		х	Х	
Decapods	х			
Barnacles			Х	
Fish	X			

Table 2. Examples of regulatory mechanisms used by aquatic organisms for several metals. (Continued)

2.2.1 <u>Cadmium</u>

<u>Active Regulation</u>: There is no evidence in the scientific literature that non-essential metals such as cadmium are actively regulated by aquatic biota (Rainbow 1996).

<u>Active Regulation/Storage</u>: Again, since no aquatic organisms are known to actively regulate cadmium, there are no examples of species that use this combined strategy. Using growth dilution, decapods are able to regulate low cadmium concentrations in a manner that approaches active regulation, but in reality is not (Rainbow et al. 1990). Accumulated cadmium in decapods is usually associated with metallothioneins and granules which may represent detoxified forms. In natural systems, where cadmium concentrations in surface waters are very low, the growth rates of organisms can dilute the cadmium concentrations in decapods. When bioavailable cadmium concentrations reach a high enough level, the detoxification system fails and mortality results.

<u>Storage</u>: Barnacles are common examples of organisms that store metals in detoxified forms. Rainbow et al. (1980), for example, demonstrated that cadmium binds to low and high molecular weight proteins in the barnacle *Semibalanus balanoides*. In shrimp, cadmium can be tolerated at concentrations significantly above 'normal' tissue levels. Because cadmium is known to be an analogue for zinc in many metalloproteins, it is possible that cadmium only becomes toxic when competing strongly with zinc for binding sites (White and Rainbow 1982). Cadmium also seems to accumulate proportionally to its exposure level in the marine isopod *Idotea baltica* and is stored in the organisms as granules in the hepatopancreas (de Nicola et al. 1993).

The scallop *Mizuhopecten yessoensis* is also a net accumulator (i.e., the uptake rate exceeds the excretion rate) of cadmium (Lukyanova et al. 1993). Cadmium was observed to accumulate to high levels in the kidney and hepatopancreas of the scallop in an age-dependent manner, even at relatively low environmental concentrations. It appears that cadmium in the scallop binds to high

April 2000 55-3690-001 (01) WCIRKLAND_I/VOLI/DATA/working/3690bioaccumulasion report2 (march 2000).doc

molecular weight proteins that have the same biological significance as metallothioneins in other animals.

Kaland et al. (1993) studied the accumulation of cadmium in the marine gastropod *Nassarius reticulatus*. Cadmium was sequestered by a minor pool of high molecular weight proteins and a major pool of proteins with molecular weights similar in size to mammalian metallothionein. In exposed organisms, cadmium was found to also bind to very low molecular weight proteins. The authors suggest that the cadmium in this pool represents the "spill over" from the detoxified cadmium bound to metallothionein-like proteins and is more metabolically available.

Spehar et al. (1978) exposed insects (*Pteronarcys dorsata* and *Hydropsyche betteni*) and a snail (*Physa integra*) to cadmium. All species were shown to be net accumulators of cadmium. Cadmium residues in *P. dorsata* and *P. integra* increased with increasing exposure concentration, while residues in *H. betteni* reached an equilibrium at higher exposure concentrations.

2.2.2 <u>Copper</u>

<u>Active Regulation</u>: Rainbow and White (1989) determined that the shrimp *Palaemon elegans* can actively regulate aqueous dissolved copper concentrations up to 100 μ g/L. As summarized in Rainbow and White (1989), other decapods known to regulate their body concentrations of copper include the lobster *Homarus gammarus*, the crab *Carcinus maenas*, and the shrimp *Crangon crangon*. The amphipod *Echinogammarus pirloti* uses a different mechanism for actively regulating internal copper concentrations. *E. pirloti* does not actively excrete excess copper, rather, it accumulates copper at a low net rate relative to its body growth rate (Rainbow and White 1989).

It appears that some species of polychaetes may also be able to actively regulate body concentrations of copper (Young et al. 1979, Pesch and Morgan 1978). Young et al. (1979) observed that copper residues in the polychaete *Eudistylia vancouveri* were relatively constant over a 33 day exposure period and that only in the highest exposure concentration did the residue concentration steadily rise during the exposure period. The authors hypothesized that the copper residues in the polychaetes were in equilibrium with the lower treatment mediums, but that regulatory abilities were exceeded in the highest copper concentration. Pesch and Morgan (1978) also suggest that the polychaete *Neanthes arenaceodentata* may be able to actively excrete excess copper from its body.

<u>Active Regulation/Storage</u>: As discussed above, many decapods are active regulators of copper. In regulating internal copper concentrations, copper is bound to metallothioneins, a process which can be of significance in detoxification (Rainbow et al. 1990). For example, after breakdown of active copper regulation, *P. elegans* can survive with accumulated copper concentrations up to approximately 700 mg/kg, suggesting that at least some of the accumulated copper is in detoxified form (Rainbow et al. 1990). In addition, copper-rich granules may be present in hepatopancreatic cells at these high copper concentrations (Rainbow et al. 1990). Consequently, although decapods actively regulate internal copper concentrations, they also have the capacity to store some excess copper in detoxified forms.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds



Storage: Like cadmium, copper binds to low and high molecular weight proteins in the barnacle *Semibalanus balanoides* (Rainbow et al. 1980). Another example of net accumulators are chironomid larvae (Timmermans and Walker 1989).

The marine gastropod (*N. reticulatus*) has been observed to accumulate copper in all tissues – but given that the gastropods were exposed to low copper concentrations it is not possible to determine their regulatory strategy because their regulatory strategy may not have been saturated (Kaland et al. 1993). Most copper was bound to proteins similar to mammalian metallothionein. In addition, Brown (1982) observed that oysters store copper in granules.

2.2.3 <u>Lead</u>

<u>Active Regulation</u>: No studies were identified in the scientific literature demonstrating that lead tissue concentrations can be actively regulated by aquatic biota. This is expected since lead is a non-essential metal and there is no evidence for active regulation of non-essential metals.

Active Regulation/Storage: No data were identified on organisms that use these combined regulatory mechanisms.

Storage: Lead will bind to metallothionein, but also has an affinity (probably higher) for other metabolic ligands as it is, often associated with deposited inorganic granules with high concentrations of calcium (Rainbow 1988). Hopkin and Nott (1979) demonstrated that the shore crab (*Carcinus maenas*) detoxifies lead in calciferous granules in the midgut gland. The midgut gland connects to the alimentary tract, where these granules have the potential to be lost through defecation.

Because lead BCF data for bivalves (discussed later in this report) tend to remain constant regardless of exposure concentration, it is likely that lead is stored in many of these organisms. This has been suggested for the zebra mussel *Dreissena polymorpha* (Bleeker et al. 1992, Kraak et al. 1994), the blue mussel *Mytilus edulis* (Talbot et al. 1976, Schulz-Baldes 1974), the Eastern oyster *Crassostrea virginica* (Pringle et al. 1968, Shuster and Pringle 1969, Zaroogian et al. 1979), and the soft-shell clam *Mya arenaria* (Pringle et al. 1968). Spehar et al. (1978) exposed insects (*Pteronarcys dorsata* and *Brachycentrus* sp.), a snail (*Physa integra*), and an amphipod (*Gammarus pseudolimnaeus*) to lead. All species were shown to be net accumulators of lead, with residues increasing with increasing exposure concentration.

2.2.4 <u>Nickel</u>

No studies were identified on the mechanisms by which aquatic biota regulate nickel. Given that it is an essential metal, and that it is a divalent metal, it is likely that the mechanisms used are similar to those for copper or zinc. That is, some organisms actively regulate nickel while others sequester it to varying degrees.

2.2.5 Silver

<u>Active Regulation:</u> No examples of organisms that use this method of regulation for silver were identified in the scientific literature.

April 2000 55-3690-001 (01) WCIRKLAND_IVOLIVDATA working 3690 bioaccumulation report2 (march 2000).doc Active Regulation/Storage: No examples of organisms that use this method of regulation for silver were identified in the scientific literature.

<u>Storage</u>: The data are very limited, but it appears that silver concentrations in the polychaete worm *Neries diversicolor* tend to be directly related to concentrations in sediments (Bryan 1979). This suggests that silver is stored in these organisms. It also appears that silver is not actively regulated in the gastropod *Littorina littorea* (tissue concentrations in the gastropod increased proportionally to the silver concentration in food items) (Bryan 1979).

2.2.6 <u>Zinc</u>

<u>Active Regulation:</u> Like copper, Rainbow and White (1989) determined that the shrimp Palaemon elegans can actively regulate aqueous dissolved zinc concentrations up to 100 μ g/L. Another closely related marine shrimp (*Palaemon serratus*) and the freshwater decapod Austropotamobius pallipes also appears to be active regulators of zinc (Devineau and Amiard Triquet 1985, Rainbow and Dallinger 1993). As summarized by Rainbow and White (1989), there is evidence that a variety of other decapods actively regulate their body concentrations of zinc, including lobster (Homarus gammarus), crab (Carcinus maenas, Maia squinado), and shrimp (Crangon crangon).

There is also evidence to suggest that the freshwater oligochaete *Lumbriculus variegatus* may actively regulate zinc, and the estuarine polychaete *Neries diversicolor* is also known to actively regulate it (Rainbow and Dallinger 1993). Also like copper, the amphipod *E. pirloti* does not actively excrete excess zinc, but takes it up at a low net rate relative to its body growth rate (Rainbow and White 1989).

<u>Active Regulation/Storage</u>: The marine mussel (*Mytilus edulis*) excretes much of the zinc that it accumulates from the kidney (George and Pirie 1980). Freshwater mussels, including *Dreissena polymorpha*, Unio pictorum, and Velesunio ambiguus also appear to regulate tissue levels of zinc (Kraak et al. 1993, Rainbow and Dallinger 1993). Accordingly, mussels are weak accumulators (or active regulators/storers) of zinc (Rainbow 1993).

The gastropod *N. reticulatus* may be able to actively regulate zinc concentrations because only minor increases in the body content of zinc were observed at very high zinc concentrations (Kaland et al. 1993). Most zinc was found to be associated with very low molecular weight proteins, although small amounts were also bound to high molecular weight components. The authors state it is unlikely that substantial amounts of zinc would be associated with intracellular granules in this gastropod.

Storage: Barnacles store very large concentrations of accumulated zinc in the form of apparently detoxified zinc phosphate granules (Rainbow and White 1989). Rainbow et al. (1980) also demonstrated that zinc binds to low and high molecular weight proteins in the barnacle *Semibalanus balanoides* (Rainbow et al. 1980). The barnacle *Elminius modestus* accumulates and stores zinc in a detoxified granular form, and therefore, the zinc in the barnacle increases with increasing zinc exposure (Rainbow and White 1989). In the Thames estuary, U.K., zinc concentrations have been measured as high as 150,000 mg/kg in the barnacle *Balanus improvisus* with, again, zinc being stored in granules in the form of detoxified zinc pyrophosphate (Rainbow et al. 1990).



Oysters (Ostrea edulis) accumulate high concentrations of zinc in detoxified granules (George et al. 1978). Accordingly, oysters are considered strong accumulators of zinc (Rainbow 1993).

Timmermans and Walker (1989) reported there was no evidence that the chironomids (midges) *Chironomus riparius* and *Stictochironomus histrio* actively regulate their zinc body burdens. Body burdens increased with increasing zinc exposure, but zinc was lost with each cast exuvium.

2.2.7 Summary

Although control mechanisms have evolved largely for essential metals, the mechanisms also operate quite successfully for many non-essential metals as well, allowing organisms to sequester, for example cadmium, mercury, and silver via metallothioneins (Viarengo 1989), cadmium via high and low molecular weight proteins (Rainbow et al. 1980), and lead in granules (Phillips and Rainbow 1989). However, there do not appear to be any examples in the literature of active regulation of non-essential trace metals (Rainbow 1996).

The key point regarding the regulation of essential metals is that bioaccumulation by organisms is an intrinsic property of these metals and is essential for life. Control mechanisms for metal bioaccumulation are fundamentally different from organic chemicals of anthropogenic origin. Hence, the application of bioaccumulation-based hazard classification criteria developed for organics appear inappropriate for use with metals. The following section provides a critical review of the bioaccumulation data for aquatic biota and demonstrates that individual BCFs for metals are not indicative of hazard potential.

2.3 RELATIONSHIP BETWEEN WATER CONCENTRATIONS AND BCFS

Many organisms can regulate metals to varying degrees. As a result, an inverse relationship between water concentrations of metals and the corresponding BCF is often observed. This relationship exists because at low water concentrations organisms are actively accumulating essential metals (and often other metals via the same uptake mechanisms) to meet their metabolic requirements. At higher water concentrations, organisms with active regulatory mechanisms are able to excrete excess metals or limit uptake. Consequently, the metal concentration in the tissue(s) of such an organism may be the same regardless of the water concentrations to which it was exposed. Despite the tissue concentrations remaining the same (or nearly the same), the BCF at the low water concentration may be quite high (suggesting high bioaccumulation potential) and the BCF at the high water concentration may be quite low (suggesting low bioaccumulation potential). In reality, the bioaccumulation potential of the metal expressed as actual body burden is the same under each scenario. To better quantify and demonstrate this relationship for different metals and organisms, a search of the scientific literature was conducted to summarize the BCF and water concentration relationship. The following summarizes this review and subsequent analyses.

For the purposes of this analysis, the review of the scientific literature was thorough, but not exhaustive. All studies were critically reviewed for quality, with the most important considerations being whether steady-state tissue concentrations were achieved in the test and whether metal concentrations were measured over the duration of the exposure period. Following U.S. EPA guidelines (Stephan et al. 1985), it was assumed that 28 days was of sufficient duration for steady

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds 10

April 2000 55-3690-001 (01) WJRKLAND_IVOLIDATA working 3690bioaccumulation report2 (march 2000).doc state to be reached in fish (if it was not clear whether steady state was reached by the end of the test). In addition, BCF data based on exposure concentrations resulting in significant effects to the exposed organisms were not used.

The following discusses the BCF data for six representative metals: cadmium, copper, lead, nickel, silver, and zinc. These metals were selected because their BCF databases are relatively large, covering a variety of species. In addition, these six metals represent both essential (copper, nickel, zinc) and non-essential metals (cadmium, lead, silver). Ranges of BCFs for different taxonomic groups are provided, as well as an evaluation of the relationship between water concentrations and BCFs for individual species. To evaluate this relationship, water concentrations and associated BCFs were plotted on a log-log scale. The relationship tends to be linear or very near linear, so linear regressions for fish species were compared to those for invertebrate species. In addition, regressions for different taxa groups (e.g., bivalves versus non-bivalves) were evaluated. If an organism actively regulates a metal, the slope of this relationship is expected to be near negative one, while the slope is expected to be near zero in an organism that stores a metal in proportion to the metal concentration in water. The slope is expected to be somewhere between negative one and zero for organisms that use a combined strategy of active regulation and storage. With the exception of algae BCF data, the results of these analyses are presented and discussed for each metal below. Algae BCF data are limited for most metals, so these BCFs are first discussed as a group.

For the six metals evaluated, algae BCF data are based on a range of exposure concentrations were typically limited to just one species. Accordingly, the BCF data across all metals were combined into a single figure (Figure 1). There is a fair amount of scatter in the data, but this is to be expected given that data were pooled for multiple metals and species, and from tests conducted in multiple laboratories using multiple test methods. Despite this scatter, there is a clear inverse relationship between the BCFs and exposure concentrations. This suggests that the metals are being regulated by a similar mechanism. The following sections demonstrate that this is a common pattern for a variety of other aquatic biota as well.

2.3.1 Metal-Specific Examples

2.3.1.1 Cadmium

Cadmium BCF data for algae are primarily limited to the diatom *Ditylum brightwellii*. The BCFs for this diatom are quite low, ranging from approximately 5 to 27 (Canterford et al. 1978). Given the continuum of regulatory strategies used by invertebrates, the BCFs for these organisms are highly variable. The largest BCF identified was 33,500 in the grass shrimp *Palaemonetes pugio* (Pesch and Stewart 1980). However, this BCF was derived based on an extremely low water concentration of 0.1 μ g/L. At a much higher water concentration of 83 μ g/L, the BCF declines drastically to 157. A similar pattern is observed in the BCF data for the amphipod *Hyalella azteca*. At water concentrations of 0.01 and 9.0 μ g/L, the BCFs are approximately 30,000 and 512, respectively (Stephenson and Mackie 1989, Borgmann et al. 1991). The BCFs for bivalves range from a low of approximately 10 in the mussel *Elliptio complanata* (Wang and Evans 1993) to approximately 3,000 in the Eastern oyster *Crassostrea virginica* (Zaroogian and Cheer 1976).

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

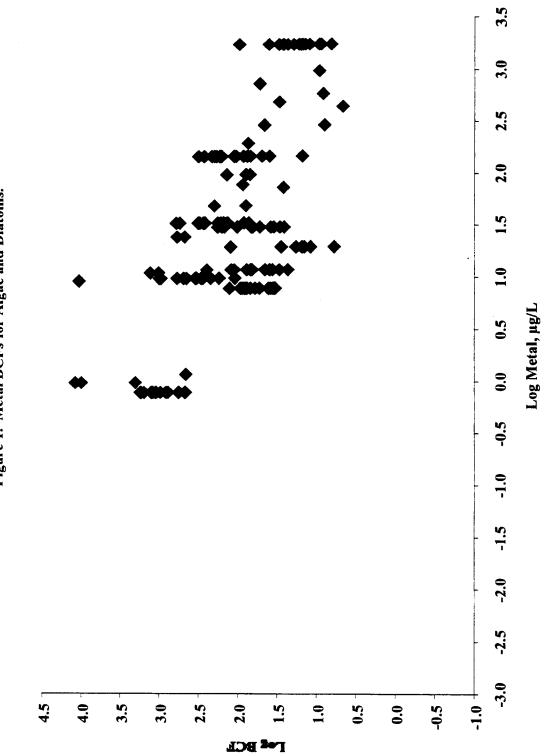


Figure 1. Metal BCFs for Algae and Diatoms.

Overall, cadmium BCFs for fish are lower than those for most invertebrates, but again, the magnitude of the BCFs tend to be dependent on exposure concentration. In one rainbow trout (*Oncorhynchus mykiss*) study, for example, BCFs ranged from 12,000 at a water concentration of 0.01 μ g/L to 200 at a water concentration of 4.8 μ g/L (Kumada et al. 1973).

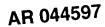
To further evaluate the inverse relationship between water concentration and BCF, species with BCFs determined over a range of water concentrations were plotted on a log-log scale. Figures 2, 3, and 4 graphically demonstrate that cadmium BCFs for most species tend to decrease with increasing exposure concentration for fish, non-bivalve invertebrates, and bivalves, respectively. The decreasing trends suggest that most fish and invertebrate species have the ability to actively regulate internal cadmium concentrations using a mechanism that appears similar to active regulation.

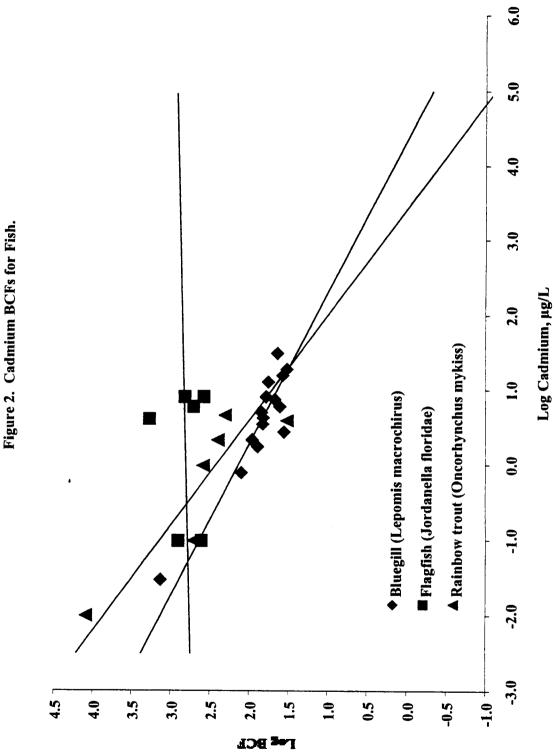
These figures clearly demonstrate that BCFs cannot be interpreted without consideration of the exposure concentrations. As discussed, the available BCFs for rainbow trout range from approximately 12,000 to 200 between exposure concentrations of 0.01 and 4.8 μ g/L. The BCF of 12,000, if considered by itself, suggests the bioaccumulation potential of cadmium is quite high, while the BCF of 200, if considered by itself, suggests the bioaccumulation potential of cadmium is relatively low. Despite the BCFs differing by a factor of 60, the tissue concentrations only differ by a factor of eight. It is more appropriate, therefore, to compare the relative BCFs between species at the same water concentrations or by considering the actual metal residues in the organisms. If the regressions in Figures 2, 3, and 4 are compared, for example, it can be discerned that fish tend to accumulate lower levels of cadmium than invertebrates. Not surprisingly, if the actual metal residues in tissue are considered, organisms that are known to store metals in detoxified forms have the highest tissue residues: bivalves, polychaetes, and insects. The residues measured in fish are two orders of magnitude lower. As discussed below, these relationships are not just relevant to cadmium, but to a variety of other metals as well.

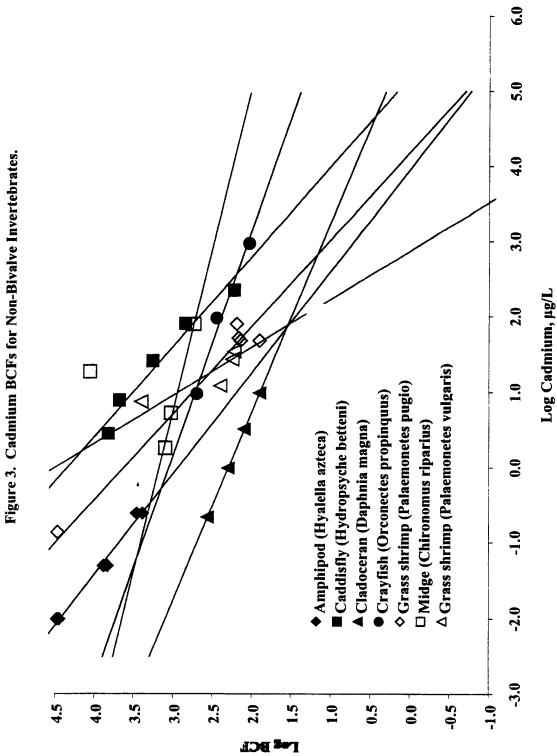
2.3.1.2 Copper

Copper BCFs for algae tend to be lower than for other types of aquatic biota, as observed for cadmium. Copper algal BCFs range from approximately 40 in the diatom *Ditylum brightwellii* (Canterford et al. 1978) to approximately 600 in the alga *Heteromastix longifillis* (Riley and Roth 1971). The BCFs for invertebrates are again highly variable due to the differing regulatory strategies of these organisms. The largest copper BCFs in invertebrates appear to be for the Eastern oyster *Crassostrea virginica*; BCFs are approximately 28,000 and 20,000 at water concentrations of 25 and 50 μ g/L, respectively (Shuster and Pringle 1969). The BCFs appear to decline with increasing exposure concentration, but the strength of this relationship is uncertain because the exposure concentrations only span a factor of two. Measured BCFs tend to be lower for non-bivalve invertebrates; they range from 442 to 10,800 in two species of amphipods (Borgmann and Norwood 1995, Ahsanullah and Williams 1991), 320 to 1,040 in isopods (Brown 1977), and 260 to 4,547 in four species of polychaetes (Millanovich et al. 1976, McKlusky and Phillips 1975).

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds







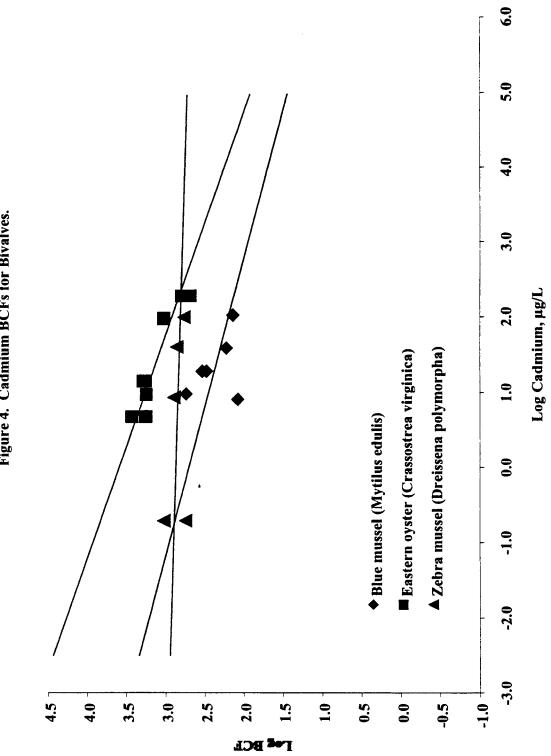


Figure 4. Cadmium BCFs for Bivalves.

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Copper BCFs were plotted versus their water concentrations to determine whether an inverse relationship also exists for copper. No appropriate whole body copper BCFs were identified for fish, but BCFs for non-bivalve invertebrates (one amphipod and two polychaetes) were determined over a range of exposure concentrations. The BCFs for all of these species were inversely related to water concentration (Figure 5). This observed relationship for polychaetes is not surprising since there is evidence that some species actively regulate their internal copper concentrations (Pesch and Morgan 1978, Young et al. 1979). A similar pattern was observed for three of the four bivalve species with sufficient BCF data, although the slopes are more variable (Figure 6). The relationship for the bay scallop *Argopecten irradians* is positive, although the mechanism for this is unclear. Zaroogian and Johnson (1983) note that weight and spawning are responsible for fluctuations in tissue copper concentrations. It is possible that "normal" variability in growth, and therefore copper concentration, may be responsible for the increasing relationship that was observed (although this was not confirmed). The species with the highest tissue residues were the Eastern oyster, an isopod, and a polychaete.

2.3.1.3 Lead

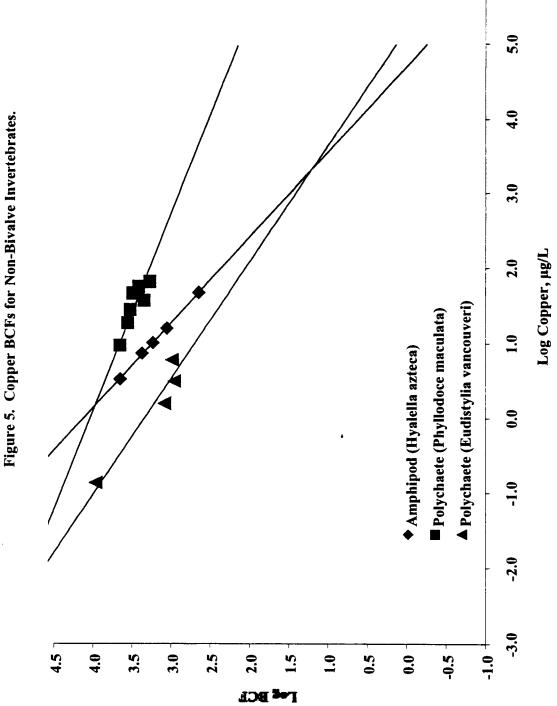
Lead BCFs in algae are quite variable and tend to be larger than those for cadmium and copper, with BCFs ranging from 26.1 in *Dunaliella tertiolecta* (Riley and Roth 1971) to 14,800 in *Selenastrum capricornutum* (Vighi 1981). The non-bivalve invertebrate with the highest measured BCF (8,000) is the isopod *Asellus meridianus* (Brown 1977). The BCFs for most other non-bivalve invertebrates are generally less than 1,000. The BCFs for bivalves tend to be higher than those for other types of invertebrates, but still less than 5,000. Lead BCFs for fish are limited, but BCFs for brook trout *Salvelinus fontinalis* were less than 100 over a range of water concentrations (Holcombe et al. 1976).

Like cadmium and copper above, BCFs measured over a range of exposure concentrations were plotted for those species with sufficient data. Figure 7 show a decreasing trend between BCFs and water concentration for an amphipod, caddisfly, stonefly, snail, and fish. A wide range of water concentrations were tested for these species, further strengthening this relationship. Conversely, lead BCFs for four species of bivalves were nearly constant over a wide range of exposure concentrations (Figure 8). This is consistent with Phillips and Rainbow's (1989) observation that bivalves tend to store lead in detoxified granules.

2.3.1.4 Nickel

Nickel BCF data are primarily limited to a cladoceran (*Daphnia magna*), three bivalve species, and a fish (*Pimephales promelas*). The cladoceran BCFs are all less than 200 (Hall 1982, U.S. EPA 1986). The measured BCFs for *Cerastoderma edule*, a bivalve, range from 3,198-59,600 (Wilson 1983), but are less than 350 for blue mussels and Eastern oysters (Zaroogian and Johnson 1984). The measured BCFs in fish are all less than 110 (Lind et al. Manuscript). The high BCFs for *C. edule* are a function of both experimental design and the propensity for this species to bioaccumulate nickel. The highest BCF (59,600) is certainly a function of extremely low water nickel concentrations (e.g., $0.1 \mu g/L$) to which they were exposed. However, even at higher water

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds April 2000 55-3690-001 (01) WCIRKLAND_IWOLIWATAIworking3690bioaccumulation report2 (march 2000).doc



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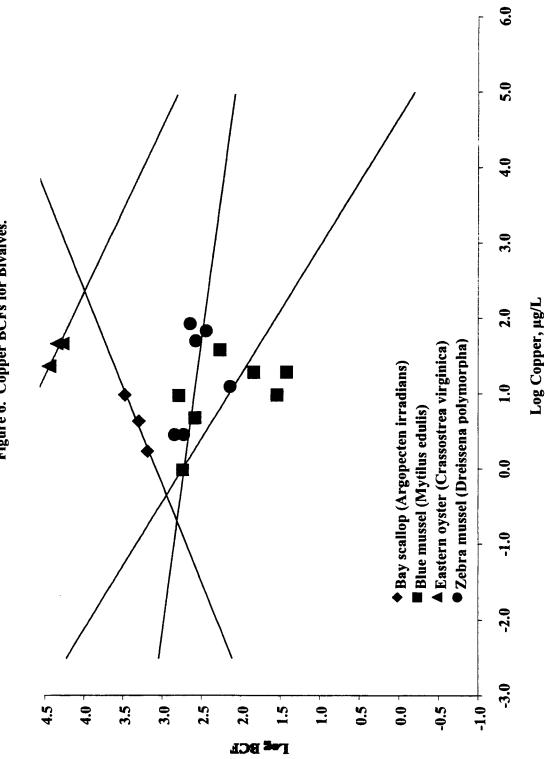
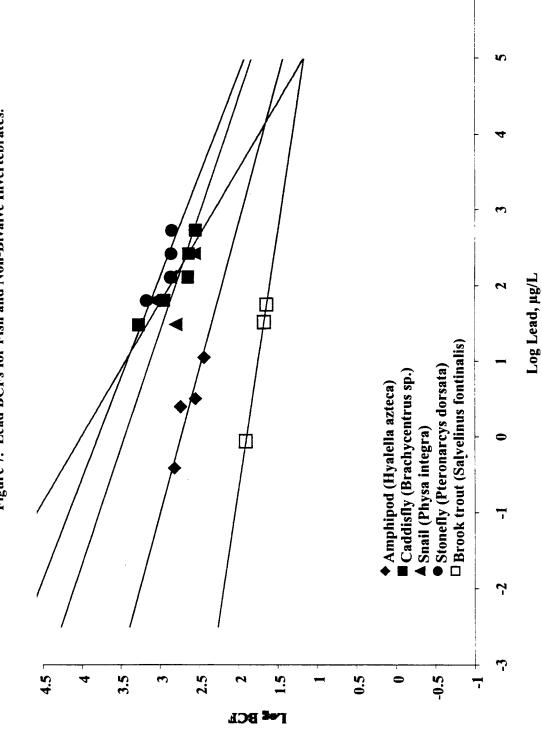
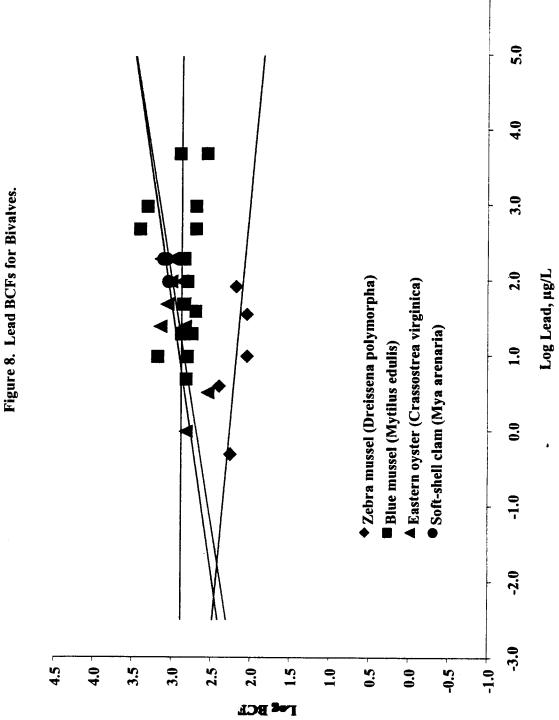


Figure 6. Copper BCFs for Bivalves.





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concentrations, *C. edule* still appears to bioaccumulate nickel to a greater extent than other species tested. For example, at $10 \mu g/L$ the BCF for *C. edule* is 3,200 compared to 164 for *Mytilus edulis* (Figure 9).

BCFs plotted versus water concentrations again demonstrated an inverse relationship in certain species. Both the bivalves and the fish showed an inverse relationship between BCF and water concentration (Figure 9).

2.3.1.5 Silver

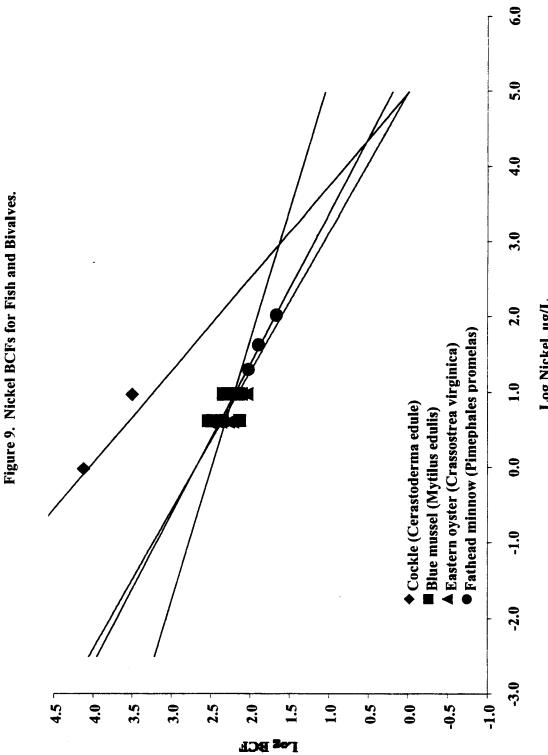
The BCF data for silver are much more limited than for the other five metals. Multiple (i.e., >1) BCFs are available for blue mussel (*Mytilus edulis*) and bluegill sunfish (*Lepomis macrochirus*) (Table 3). An inverse relationship was observed for the blue mussel, while an increasing relationship was observed for bluegill. The BCFs for bluegill sunfish surprisingly increase with increasing exposure concentration (U.S. EPA 1987b). The mechanism for this, if the data are accurate, is unclear. The relationship is only based on two data points from one study, so the results should be interpreted cautiously. Nehring (1976) evaluated silver concentrations in mayflies (*Ephemerella grandis*) and stoneflies (*Pteronarcys californica*) exposed to silver in the laboratory. Silver concentrations were only measured in dead organisms, so the results were not included in the database. However, given that data for silver are lacking, the results from this study are briefly summarized here. Mayfly and stonefly BCFs in dead organisms ranged from 17-84 and 14-37, respectively (assuming a moisture concentrations.

	Tissue Conc. (µg/kg		
Species	Water Conc. (µg/L)	ww)	BCF
Bluegill (Lepomis macrochirus)	10	150	15
	100	15,000	150
Blue mussel (Mytilus edulis)	1	765	765
	5	775	155
	10	1,055	106

Table 3. Silver BCF data for species with more than one data point.

2.3.1.6 Zinc

Zinc BCFs for algae are quite variable, ranging from 50 in the alga *Olisthodiscus luteus* (Riley and Roth 1971) to 12,000 in the diatom *Thalassiosira pseudonana* (U.S. EPA 1987c). Measured zinc BCFs in non-bivalve invertebrates range from as low as one in the crayfish *Oronectes virilis* (Mirenda 1986a) to 2,640 in the amphipod *Hyalella azteca* (Borgmann et al. 1993). Measured BCFs in some bivalves are higher, being as high as 27,080 in the Eastern oyster (Shuster and Pringle 1969). Measured BCFs in fish are much greater than in the other metals discussed above. In Atlantic salmon (*Salmo salar*), for example, BCFs are as high as 14,000 (Farmer et al. 1979) and as high as 5,800 in the flagfish *Jordanella floridae* (Spehar et al. 1978).



Log Nickel, µg/L

As for most of the other metals, an inverse relationship between BCF and water concentration was observed for zinc in bivalves, non-bivalve invertebrates, and fish. The slope was very steep for three of four fish species, but fairly flat for a fourth (*Poecilia reticulata*) (Figure 10). The lack of an observed relationship in *P. reticulata*, however, may simply be due to the narrow concentration range to which fish were exposed (i.e., less than a factor of four difference). This inverse relationship is expected since fish tend to be active regulators of zinc (Phillips and Rainbow 1989). The BCF-water concentration relationship for two species of amphipods are remarkably similar (Figure 11). This strong negative relationship is not surprising since the regulatory strategy of some amphipods (e.g., *Echinogammarus pirloti*) approaches that of active regulation (Rainbow and White 1989).

This amphipod technically does not actively regulate, but its uptake of zinc is so slow that it appears to actively regulate via growth dilution (Rainbow and White 1989). Lastly, inverse relationships were observed in four species of bivalves (Figure 12). It is somewhat surprising that a strong decreasing trend is observed for the Eastern oyster since some oyster species are known to store high zinc concentrations in detoxified granules (George et al 1978). In organisms with this regulatory strategy, the BCF tends to be constant. The apparent decreasing relationship may simply be a function of limited data for the Eastern oyster.

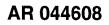
2.3.2 Interpretation

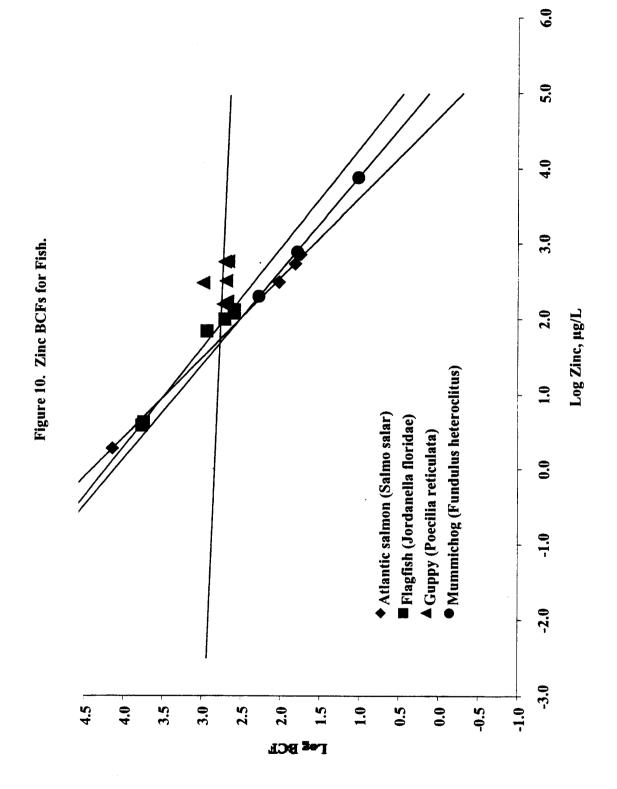
Several observations can be made from the data presented. First, the slopes of the BCF and water concentration relationships for the essential metal zinc are much steeper than those for the non-essential metal lead. Even for non-bivalve invertebrates, the slopes for lead tend to be much more shallow for most species. This provides further support that zinc is more actively regulated than lead. The slopes for lead and zinc appear to represent the two extremes. The slopes for other metals, such as cadmium and copper, tend to fall somewhere between those for lead and zinc. The mechanistic reasons why this occurs is unclear.

Second, these examples provide additional evidence that BCFs are a function of regulatory mechanisms and that single BCFs do not predict the bioaccumulation potential of metals in most organisms due to the inverse relationship between BCF and water concentration. Similar to the algae BCF data plotted in Figure 1, if all BCFs for fish are graphed, a clear decreasing trend is again observed between different species and metals (Figure 13). Again, this demonstrates that metals in fish are regulated by similar mechanisms. Moreover, this figure clearly shows that the inverse relationship between BCFs and water concentrations is important for multiple metals.

The primary principle behind using BCFs in hazard classification is that chemicals with large BCFs have the potential to reach high tissue concentrations and result in long-term direct toxicity or secondary poisoning. The following sections discuss the relationship between BCF, tissue residue concentration, and potential for long-term (chronic) toxicity and/or secondary poisoning.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds





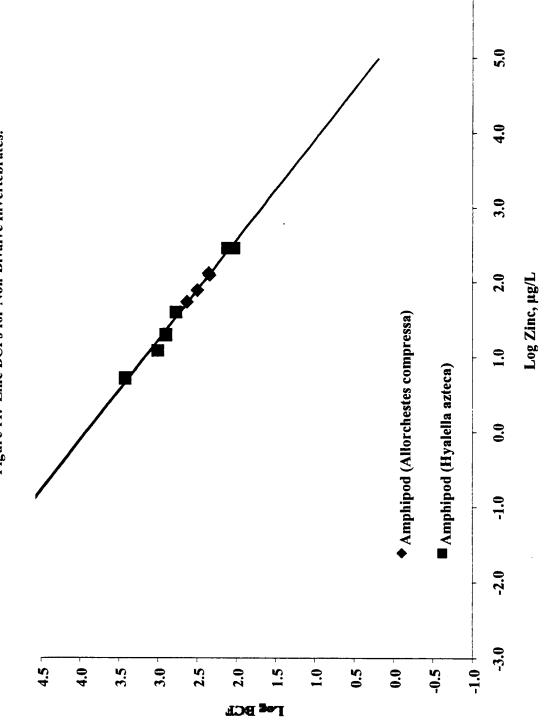


Figure 11. Zinc BCFs for Non-Bivalve Invertebrates.

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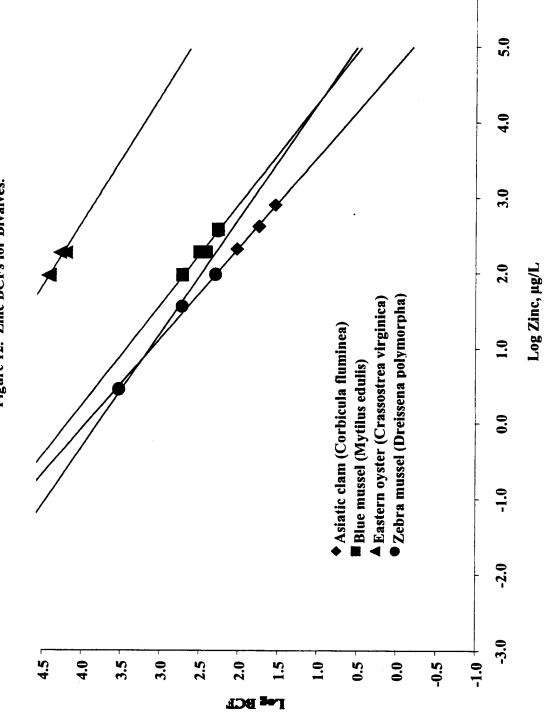


Figure 12. Zinc BCFs for Bivalves.

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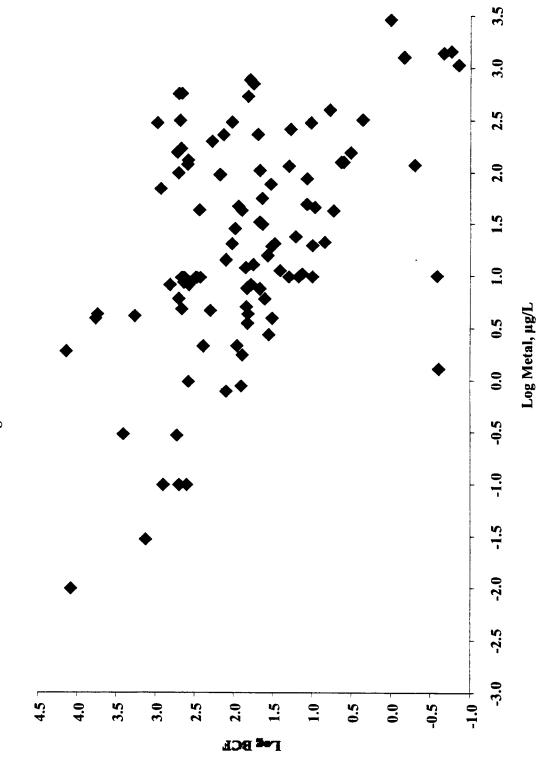


Figure 13. Metal BCFs for Fish.

2.4 BIOACCUMULATION AS AN INDICATOR OF CHRONIC TOXICITY FOR METALS AND METAL COMPOUNDS

The concept that BCFs can be used as an indicator of chronic toxicity stems from the assumption that larger BCFs are indicative of higher tissue concentrations, which in turn result in direct or secondary toxicity. This concept is primarily relevant to organic chemicals with narcosis as the mode of toxic action (Veith et al. 1985, McCarty 1986). An organic chemical's bioaccumulation potential is often related to its lipophilicity, as measured by its octanol-water partition coefficient (K_{ow}) (Veith and Kosian 1982). Chemicals with a high K_{ow} have a slow uptake rate in organisms and an even slower excretion rate (Veith et al. 1979, Spacie and Hamelink 1982).

This relationship results in two general trends: (1) the acute toxicity of high K_{ow} compounds is relatively low because uptake is limited during short-term exposures; and (2) the low excretion rates can result in chronic toxicity at levels much lower than that observed for acute toxicity (i.e., large acute-chronic ratios). Consequently, organic chemicals with a high K_{ow} have the potential for chronic toxicity at concentrations much lower than those observed for acute toxicity (i.e., the chronic toxicity potential of high K_{ow} compounds is greater). Hydrophobicity, as measured by K_{ow} , can be used to explain and predict toxicant kinetics and effects, but as noted by McCarty (1986), this interrelationship may be of utility for many organics but will not apply to all chemicals. For metals, Winner (1984) states that studies have shown that accumulated metal may be poorly, or even negatively, correlated with toxicity. For example, a negative correlation between whole body bioaccumulation and toxicity of copper in rainbow trout has been demonstrated (Dixon and Sprague 1981), possibly due to the induction of metallothionein (Winner 1984) and due to a lack of measurement of copper at the site of action where the toxicity occurs.

Simply put, the bioaccumulation potential of a metal based on whole body measurements is not indicative of its toxicity because aquatic organisms have regulatory mechanisms for actively excreting excess metal and/or for storing excess metal in detoxified forms. Additionally, metals only appear to become toxic when these regulatory mechanisms are overwhelmed (Phillips and Rainbow 1989, Bryan 1979) and when the concentration at a site of toxic action exceeds a toxic Obviously at high enough exposures, bioaccumulation in an organism overloads threshold. regulatory mechanisms and exceeds a toxicity threshold at a site of toxic action. This unpredictability of BCFs stems from two primary factors. First, as demonstrated above, BCFs are a poor indicator of bioaccumulation potential in a variety of organisms because BCFs are often inversely related to exposure concentration. The data on rainbow trout exposed to cadmium in the previous section provided a good example of this. Second, bioaccumulation potential is a poor indicator of toxicity because many organisms can store metals in detoxified forms. Consequently, the bioaccumulation potential in these organisms may be high, but the potential for toxicity is negligible. Issues associated with the relationship between bioaccumulation and toxicity of metals are discussed further below with specific examples provided.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

2.4.1 Relationships Between BCFs and Chronic Toxicity

To demonstrate the lack of relationship between the magnitude of the whole body BCF and the chronic toxicity of metals, a series of figures were developed to graphically display the data. In Figure 14, the mean, minimum, and maximum BCFs (fish and invertebrates) for five metals are plotted against their chronic toxicity as defined by the U.S. EPA ambient water quality criteria for each metal (U.S. EPA 1985b,d,e, U.S. EPA 1986, U.S. EPA 1987c). Other regulatory agencies have developed alternative criteria, but the general relationships between metals are the same. As shown in the plot, cadmium is the most toxic of the metals evaluated and nickel the least toxic. Because BCFs for metals are highly dependent on exposure concentration for many aquatic organisms, we only plotted the BCFs that were based on exposure concentrations at the chronic criterion and ten times the chronic criterion. For example, the U.S. EPA chronic criterion for cadmium is 1.1 µg/L; therefore, only BCFs derived at water concentrations between approximately 1 and 11 µg/L were plotted. This ensures that very high or very low BCFs for a metal, based on exposure to very low or very high metal concentrations in water, are not over represented in the figures and adding bias to the comparison between BCFs and chronic toxicity potential. As shown in Figure 14, no relationship between the magnitude of the BCF and chronic toxicity is apparent based on this figure. For cadmium and zinc, the mean, minimum, and maximum BCFs are almost identical despite the chronic criterion for cadmium being 120 times lower than the zinc criterion.

Evaluating a single species and a single metal, the study by Borgmann et al. (1978) provides further evidence that there is no relationship between the magnitude of a BCF and direct toxicity. Borgmann et al. exposed aquatic snails (*Lymnaea palustris*) to lead nitrate for 120 days. Results from this study are summarized in Table 4. The study demonstrated that increased toxicity is not necessarily observed in organisms with larger BCFs. The percent survival in snails with a lead BCF of 2,500 was not less than the percent survival in snails with a lead BCF of 304. Further, the same levels of toxicity are not observed in organisms with similar BCFs. The percent survival in three groups of snails, all with lead BCFs of approximately 2,500, ranged from 15-79 percent. At a low water concentration, the lack of a relationship between the BCF and toxicity is again a function of the inverse relationship between the BCF and water concentration. At higher water concentrations the BCF is fairly constant, demonstrating that tissue concentrations were increasing in proportion to exposure concentrations. At these concentrations, the results demonstrate that toxicity is not related to the BCF but, rather, must be related to the actual tissue concentration.

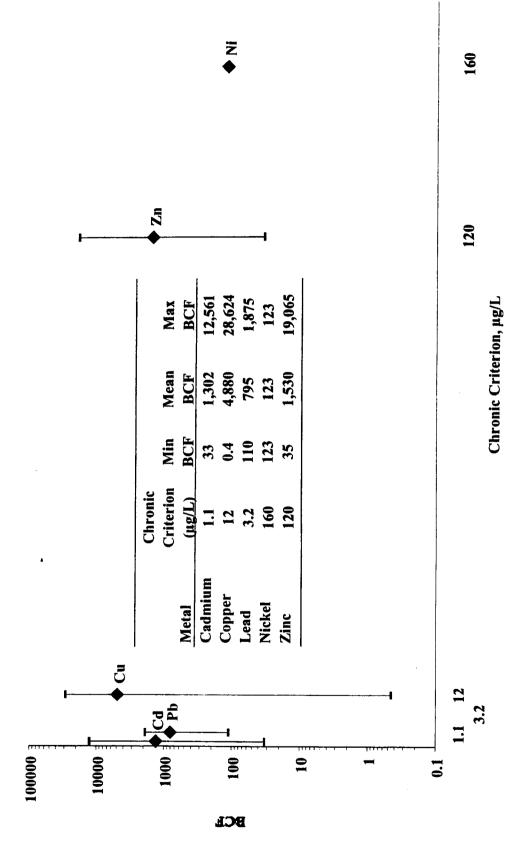
Water Conc. (µg/L)	Whole Body Tissue Conc. (mg/kg ww)	BCF	% Survival
3.8 (control)	1.2	300	69
12	30.4	2,500	79
19	47.0	2,500	39
31	71.2	2,300	15
54	NR	NA	2
97	NR	NA	0

Table 4. Relationship between lead BCFs and toxicity in the snail Lymnaea palustris (Borgmann et al. 1978).

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds 30

April 2000 55-3690-001 (01) WKIRKLAND_IVVOLIVDATA working 3690bioaccumulation report2 (march 2000.doc





In organisms that do not regulate metals by active excretion, but store them in detoxified forms, there also does not appear to be any relationship between bioaccumulation potential and toxicity. Since these aquatic organisms can bioaccumulate large amounts of metal without overloading their storage mechanisms, bioaccumulation potential is clearly not indicative of the metal's potential to exert toxicity. The barnacle *Elminius modestus*, for example, accumulates zinc at a high rate with no apparent significant excretion (Rainbow 1996). Concentrations in some barnacles may reach 100,000 mg/kg dw without any known deleterious effect on the organism.

Based on the BCFs for multiple metals (arsenic, cadmium, copper, lead, nickel, selenium, and zinc) presented in previous figures, it is clear that the BCF for most types of organisms is dependent on the exposure concentration. Although the observed BCFs are clearly variable and overlap between metals, no relationship exists between the magnitude of a metal's BCF and its direct toxicity potential.

2.4.2 Species Sensitivity Distributions

As explained above, metal BCFs and bioaccumulation potential are influenced by the regulatory mechanisms used by aquatic organisms. The toxicity of metals to aquatic biota is also directly related to their regulatory mechanisms because toxicity is observed when these regulatory mechanisms are overloaded (Phillips and Rainbow 1989). Accordingly, the regulatory mechanism influences metal bioaccumulation, BCFs, and toxicity. To further evaluate the relationships between regulatory mechanism, bioaccumulation potential, and toxicity, large databases of acute toxicity data for metals were analyzed. It was not possible to analyze chronic toxicity data because they are available for only a limited number of species. These databases contain toxicity data for diverse groups of freshwater and marine organisms with different regulatory strategies, including: cladocerans, copepods, amphipods, bivalves, oligochaete worms, polychaete worms, gastropods, decapods, aquatic insects, and several fish species. In evaluating the species sensitivity distributions for cadmium, copper, nickel, silver, and zinc, it is clear that certain taxonomic groups have similar relative sensitivities to these metals (Brix et al. 2000a,b).

As discussed in Section 3.2, the marine decapod P. elegans regulates copper and zinc over a wide range of metal concentrations. Other decapods, including lobsters and crabs, are also known to actively regulate copper and zinc. Apparently, active regulation of essential metals by decapods is not necessarily restricted to older life stages of organisms, such as juveniles and adults. Larvae of the prawn Palaemon serratus, for example, have been reported to regulate zinc (Devineau and Amiard-Triquet 1985). It is presumed that embryos lack sufficiently developed organs to actively regulate or detoxify metals. As such, these life stages are assumed to be more sensitive to metals. The marine amphipod E. pirloti accumulates zinc, but the rate of net uptake is very slow. In addition, this amphipod also accumulates copper with no evidence of active regulation. At the other extreme, the barnacle E. modestus accumulates high levels of copper and zinc in detoxified granules with no significant excretion. The data for marine gastropods suggest that regulation of zinc is species-specific. For example, Littorina littorea is known to store zinc and other metals in detoxified granules (Mason and Nott 1981), while Kaland et al. (1993) suggest that Nassarius reticulatus may be able to actively regulate zinc to some degree. As for non-essential metals, the decapod, amphipod, and barnacle all accumulate cadmium with no active regulation. Given the above information, the relative sensitivities of these organisms, and related organisms, were then

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

April 2000 55-3690-001 (01) \KIRKLAND_I\VOLI\DATA\morking\3690bioaccumulation report2 (march 2000).doc compared to determine whether a relationship may exist between sensitivity and regulatory mechanism.

2.4.2.1 Cadmium

Saltwater Organisms. The available toxicity data for cadmium suggest that, overall, decapod crustaceans are the most sensitive taxonomic group (Figure 15). Toxicity data are available for multiple life stages of crabs, shrimp, and lobsters, and early life stages are more sensitive than older life stages. This is not surprising given that early life stages are expected to be more sensitive due to their underdeveloped regulatory abilities and that older life stages of decapods tend to be active regulators that are unable to detoxify excess metal. Amphipods, in contrast to decapods, do not appear to excrete excess metal or have well developed storage mechanisms for metals, rather, they tend to regulate metals by having a very slow uptake rate. As a result, amphipods would be expected to have a moderate to high sensitivity to cadmium after a sufficient exposure time. However, amphipods actually appear to be of moderate to low sensitivity. The basis for this result is not entirely clear, but it may be that their relatively slow uptake rates reduce their relative sensitivity in short-term acute toxicity tests. At least some species of gastropods are known to bind metals with metallothionein and other organoproteins (Kaland et al. 1993). This may explain why gastropods tend to have a relatively low sensitivity to cadmium (Figure 15). Worms appear to have variable regulatory strategies between species, so it is not surprising that the sensitivities of worms relative to other organisms is quite variable (Figure 15). Overall, the data suggest that organisms with negligible regulatory abilities (e.g., embryos) or active regulation tend to be more sensitive to cadmium. These organisms tend to have limited mechanisms for storing detoxified metals and, hence, cannot tolerate very high levels of a non-essential metal such as cadmium.

Freshwater Organisms. The freshwater taxa most sensitive to cadmium are cladocerans and amphipods, while the least sensitive taxa include insects and worms (Figure 16). Limited data were identified in the literature on the mechanisms used by cladocerans to regulate metals, but since they do not bioaccumulate cadmium to high levels (Figure 3), it is unlikely that they are able to store large amounts of detoxified cadmium. Griffiths (1980) observed calcium granules in *Daphnia magna* exposed to cadmium, but it is not clear if these granules act as a detoxifying mechanism. Bodar et al. (1990) and Stuhlbacher et al. (1992) studied cadmium resistance in *Daphnia magna* and determined that resistance was a physiological response, not hereditary. *Daphnia* that were pre-exposed to cadmium tended to accumulate more cadmium than daphnids that were not pre-exposed. It is possible that cadmium was being bound by metallothionein-like proteins (Bodar et al. 1990, Stuhlbacher et al. 1992). Given that there is little evidence to suggest that any organism can actively regulate the non-essential metal cadmium, it is likely that the limited storage capacity that daphnids may have when not pre-exposed to cadmium is quickly overwhelmed and toxicity results at relatively low concentrations.

Amphipods, in general, also do not appear to have well developed storage mechanisms for metals. Rather, they tend to regulate metals by having a very low net uptake rate. Similar to cladocerans, therefore, they may be among the more sensitive species to cadmium because they have a limited ability to store the metal in a detoxified form. In contrast, aquatic insect larvae do store metal. Consequently, these organisms generally have the capacity to store large amounts of metal in a

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds 33

April 2000 55-3690-001 (01) \KIRKLAND_1\V0L1\DATA\working\3690bicaccumulation report2 (march 2000).doc

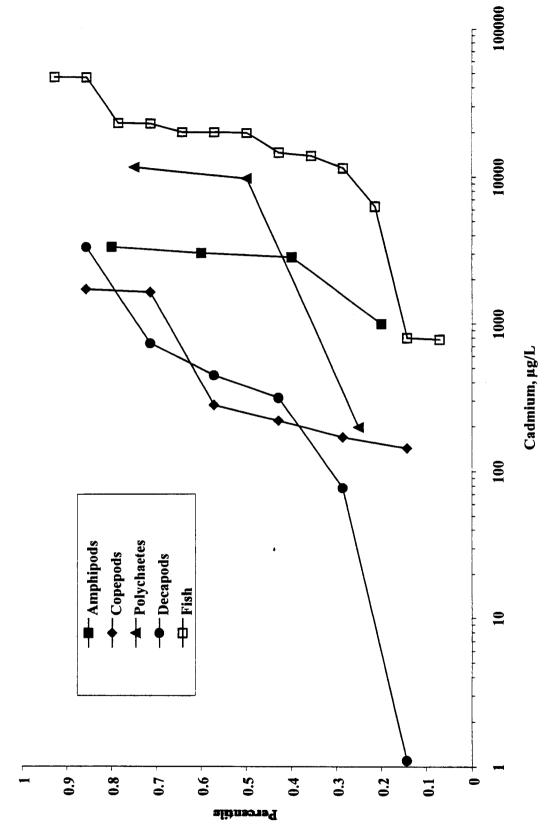
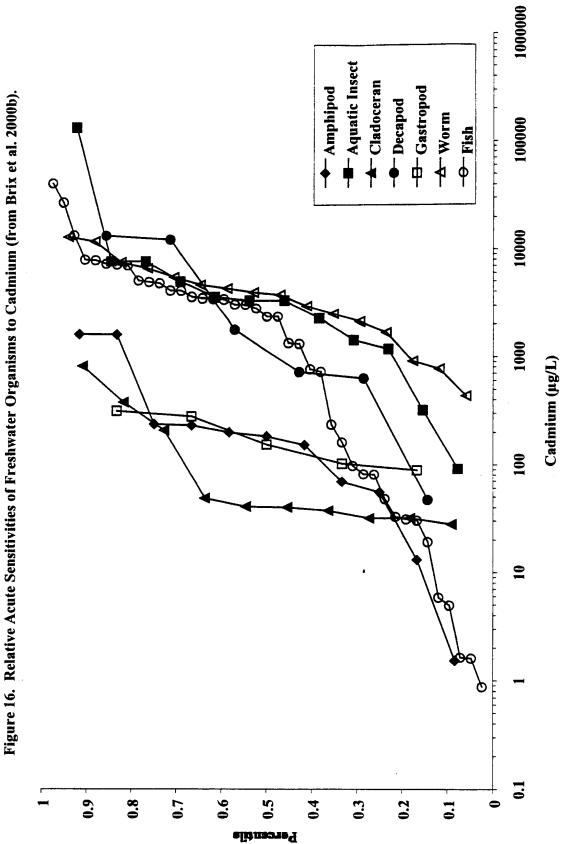


Figure 15. Relative Acute Sensitivities of Saltwater Organisms to Cadmium (from Brix et al. 2000b).



detoxified form. There are many factors that influence the sensitivities of organisms to a metal, but the above examples suggest that the regulatory mechanisms of aquatic biota may be a significant factor. Since the regulatory strategy of an aquatic organism profoundly influences the bioaccumulation potential of a metal within an organism, these examples provide further evidence that bioaccumulation potential cannot be correlated with the potential for toxicity. The above examples, may even suggest an opposite relationship exists, i.e., bioaccumulation potential and toxicity potential of metals are inversely related as a function of metal regulatory strategy. Organisms that bioaccumulate large concentrations of metals do so because they have the necessary storage mechanisms to detoxify the metal; organisms without the ability to store metals in detoxified forms generally are more sensitive and bioaccumulate lower concentrations of metals.

2.4.2.2 Copper

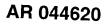
Saltwater Organisms. The most sensitive species to copper that have been tested include early life stages of bivalves and fish (Figure 17). Of the five most sensitive species to copper, the life stage for four was the embryo (three bivalves and one fish species) and newly hatched nauplii in the fifth (a copepod). As discussed above, early life stages of organisms such as these embryos, in particular, generally have underdeveloped regulatory abilities compared to adult organisms. Toxicity data are also available for larvae of the barnacle (Balanus improvisus). Presumably due to the lack of detoxification mechanisms at this life stage, larvae of this barnacle are of moderate sensitivity, rather than low sensitivity as would be expected given the high copper storage capacity of adults. Toxicity data are available for five species of decapods. Given that decapods can generally actively regulate copper, it was expected that these organisms would be among the more sensitive invertebrates. Instead, however, the decapods have a wide range of sensitivities to copper. Dungeness crab (Cancer magister) larvae are fairly sensitive, but green crab larvae (Carcinus maenas) are over an order of magnitude less sensitive. The polychaete Nereis does not appear to regulate copper (Leland and Kuwabara 1985), but stores it in detoxified forms. This is consistent with the available toxicity data for copper, as Nereis diversicolor is one of the least sensitive marine species that have been tested.

Freshwater Organisms. The species sensitivity distribution for copper is very similar to that observed for cadmium (Figure 18). Cladocerans and amphipods again appear to be the most sensitive invertebrates, while insects appear to be the least sensitive. Although copper is an essential metal and cadmium is non-essential, it is probably due to similar mechanisms that this same relative pattern between taxa is observed. One difference being that organisms can tolerate higher concentrations of copper than cadmium.

2.4.2.3 Nickel

Saltwater Organisms. Given that the toxicity data for nickel are much more limited than for cadmium and copper, and the strategies used by aquatic organisms to regulate nickel are not well known, it is difficult to identify relationships between sensitivity and regulatory strategy. The available data demonstrate that mysids are among the most sensitive organisms that have been tested (Figure 19). The data for bivalves again demonstrate the importance of life stage. The two most sensitive bivalve data points are based on the embryo life stage, while the least sensitive life

April 2000 55-3690-001 (01) WCTRKLAND_IVOLIDATA\working\3690bioaccumulasion report2 (march 2000).doc



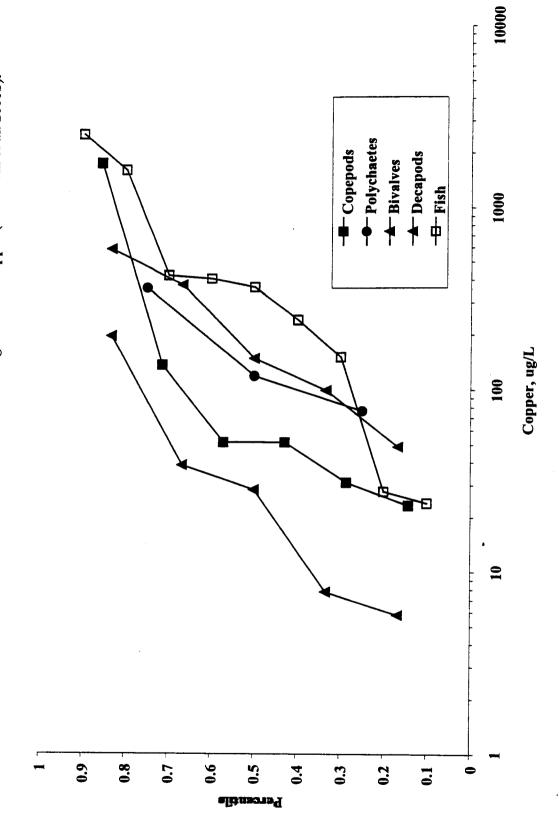


Figure 17. Relative Acute Sensitivities of Saltwater Organisms to Copper (from Brix et al. 2000b).

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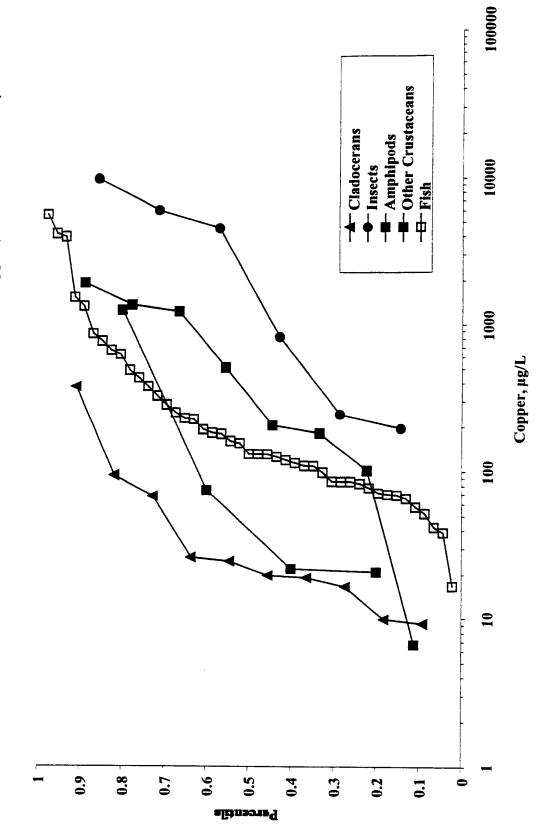


Figure 18. Relative Acute Sensitivities of Freshwater Organisms to Copper (from Brix et al. 2000a).

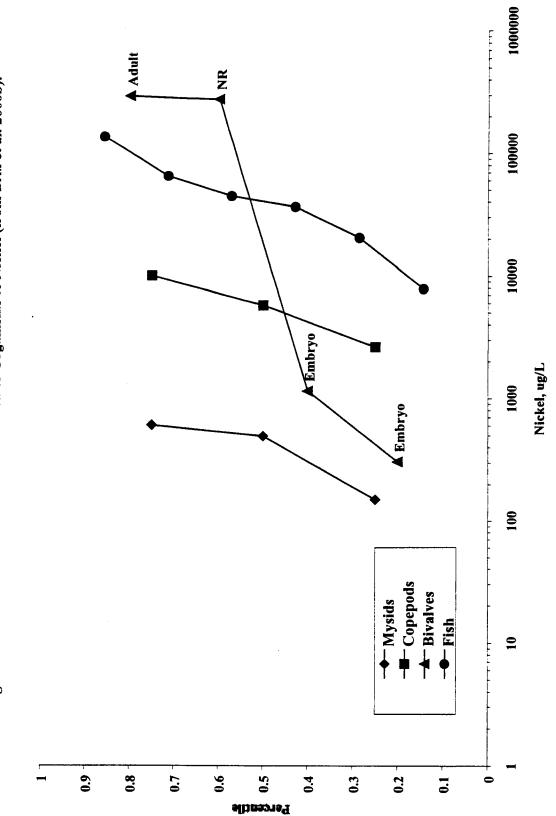


Figure 19. Relative Acute Sensitivities of Saltwater Organisms to Nickel (from Brix et al. 2000b).

stage is based on an adult (the life stage of the third most bivalve was not reported). Bivalve embryos do not have the ability to actively regulate or sequester excess nickel and, therefore, are much more sensitive. Older life stages are much less sensitive despite the fact that they are likely to have much higher BCFs.

Freshwater Organisms. The nickel toxicity data for freshwater organisms again demonstrate that cladocerans are among the most sensitive species and aquatic insects are among the least sensitive species (Figure 20). Although the regulatory mechanisms have not been well studied, it can probably be assumed that cladocerans have limited ability to sequester excess nickel, while insects can sequester large amounts.

2.4.2.4 Silver

Saltwater Organisms. Toxicity data for silver are not available for a sufficient number of saltwater species to evaluate the relationship between sensitivity and regulatory strategy.

Freshwater Organisms. Silver toxicity data for freshwater organisms are somewhat limited, but again cladocerans, along with amphipods, appear to be the most sensitive organisms tested (Figure 21). Insects are again generally less sensitive, suggesting that they can sequester silver in non-toxic forms.

2.4.2.5 Zinc

Saltwater Organisms. Like copper, the most sensitive species to zinc are bivalve and fish embryolarvae (Figure 22). As demonstrated in the figure, storage mechanisms develop with age and the sensitivities of juvenile and adult bivalves lessen compared to embryo-larval life stages. This is an important point because it provides further evidence that BCFs are not related to the sensitivity of organisms to metals. Relatively high BCFs are often associated with adult bivalves, but adult bivalves tend to be some of the least sensitive organisms/life stages to metal toxicity. Interestingly, decapods have a range of sensitivities, even considering that many are known to be active regulators. This again may be explained by the slow uptake rate for some species.

Freshwater Organisms. The relative sensitivities of various taxa to zinc is again similar to the relative sensitivities to copper and cadmium (Figure 23). Cladocerans and insects are again the most and least sensitive taxonomic groups tested, respectively. The toxicity data for zinc further support that the sensitivity of organisms is a function of their regulatory mechanisms, and not the bioaccumulation potential of a metal.

2.4.2.6 Conclusions from Species Sensitivity Distributions

Among freshwater organisms, cladocerans tend to be the most sensitive taxonomic group to all of the metals evaluated, while insects tend to be the least sensitive, or among the least sensitive, taxonomic group (Brix et al. 2000a,b). The difference in sensitivities between these two taxonomic groups can probably be partially explained by their different regulatory strategies. As discussed, no data were identified on whether cladocerans actively regulate essential metal. Their ability to

April 2000 55-3690-001 (01) \KJRKLAND_I\VOLI\DATA\working\3690bioaccumulation report2 (march 2000).doc

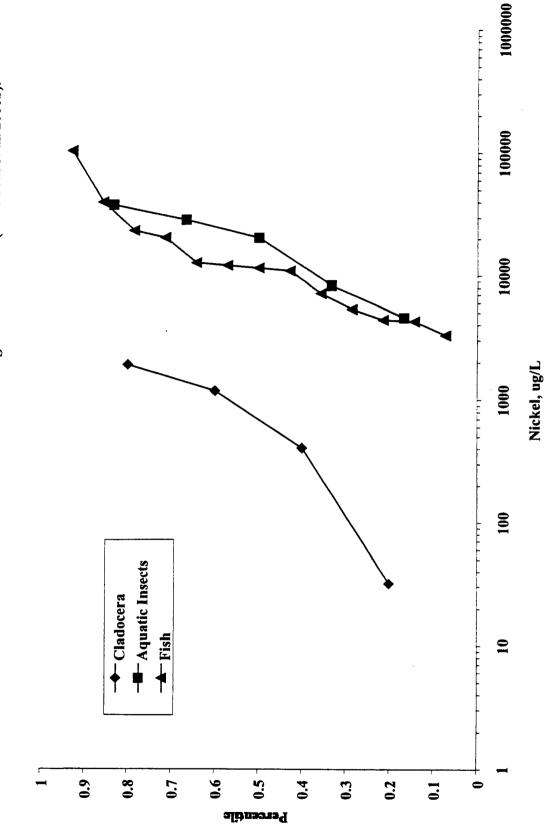


Figure 20. Relative Acute Sensitivities of Freshwater Organisms to Nickel (from Brix et al. 2000b).

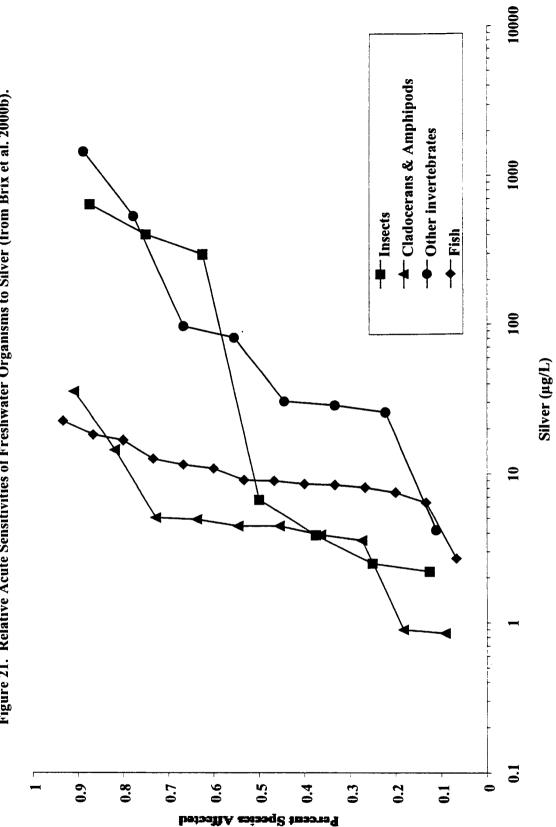


Figure 21. Relative Acute Sensitivities of Freshwater Organisms to Silver (from Brix et al. 2000b).

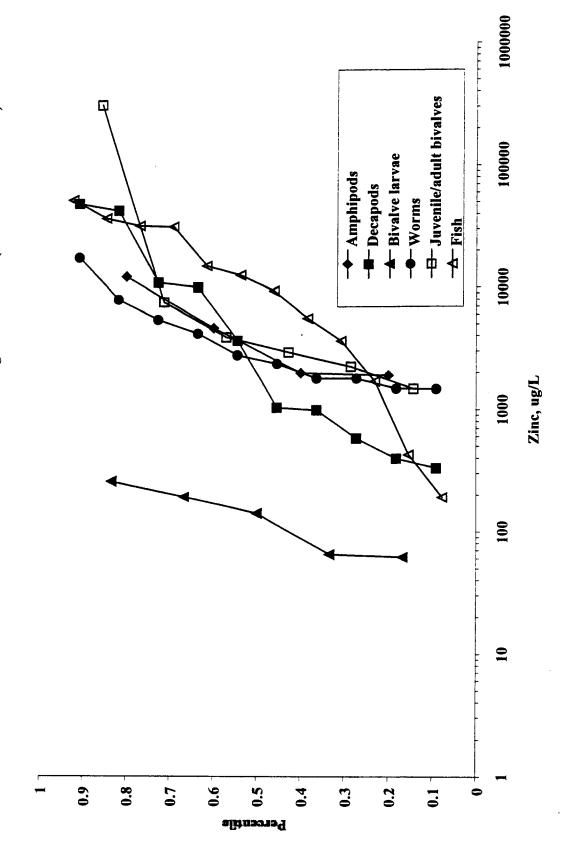


Figure 22. Relative Acute Sensitivities of Saltwater Organisms to Zinc (from Brix et al. 2000b).

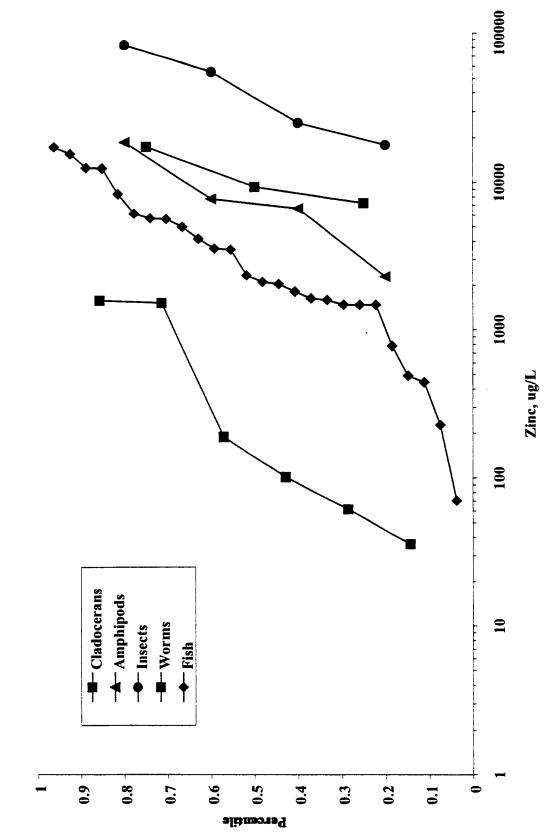


Figure 23. Relative Acute Sensitivities of Freshwater Organisms to Zinc (from Brix et al. 2000b).

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detoxify metals using metallothionein-like protein, however, seems to be limited unless they are pre-exposed to a metal. Because they have limited ability to detoxify metals, their regulatory mechanisms are rapidly overwhelmed and toxicity results. Conversely, aquatic insect larvae appear to be net accumulators of heavy metals (Rainbow and Dallinger 1993). Because insect larvae can store metals in non-toxic forms, they can regulate larger metals concentrations and, accordingly, are less sensitive to the toxic effects of metals.

A similar pattern is observed for saltwater organisms. The most sensitive species tend to be embryos/larvae with undeveloped or poorly developed regulatory systems or certain decapods that are known to be active regulators. These types of organisms have a limited ability to sequester excess metals and, as a result, tend to be among the more sensitive species. Other organisms, such as polychaetes tend to be less sensitive – many of these organisms are known to store metal in detoxified forms. Consequently, they have a greater ability to sequester excess metal and are not as sensitive.

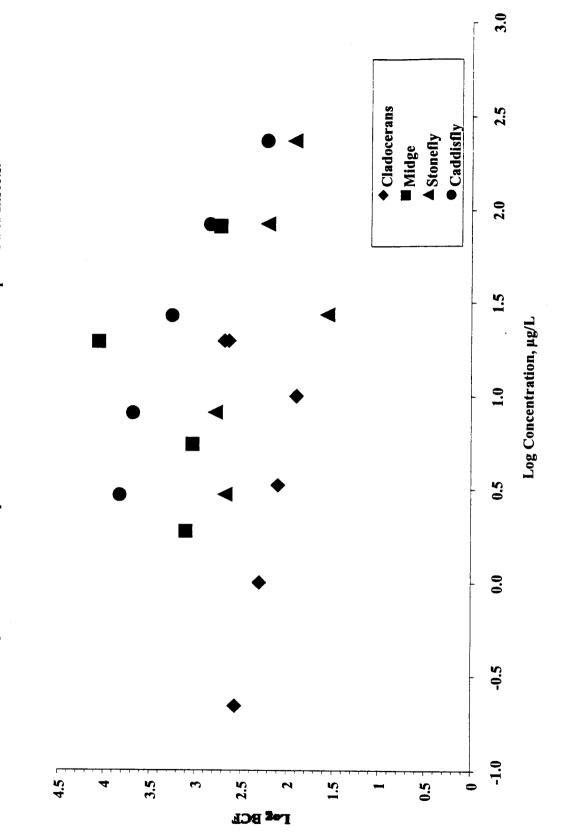
These relationships provide further support that bioaccumulation potential has no relationship to toxicity. Several cladoceran and aquatic insect BCFs are available for cadmium, for example (Figure 24). As the figure shows, most BCFs for aquatic insects are greater than those for cladocerans, despite the sensitivities of cladocerans being much greater than for insects. If anything, an inverse relationship between bioaccumulation potential and sensitivity may exist since those organisms that can bioaccumulate metals in non-toxic forms tend to be the least sensitive.

2.5 SECONDARY POISONING AND BIOMAGNIFICATION OF METALS AND METAL COMPOUNDS

Secondary poisoning results when toxicant concentrations in an organism reach a level that is toxic to the organisms that feed on it. Substances that bioaccumulate or biomagnify in food webs often are considered to have the greatest potential to cause secondary poisoning. Biomagnification is the process by which tissue concentrations of a bioaccumulated substance increase as it is passed up the food web through at least two trophic levels. Polychlorinated biphenyls (PCBs) and the organochlorine pesticide DDT are common examples of chemicals that biomagnify in food webs (Eisler 1986, Keith 1996). Woodwell et al. (1967), for example, observed that DDT concentrations were found to increase in step-wise fashion from one trophic level to the next, and measured DDT residues in birds were approximately one million times greater than the concentrations in water. The concern with these types of chemicals is that seemingly low environmental concentrations can have population-level effects in organisms in the upper levels of food webs. As discussed in this section, however, there is little evidence to suggest that metals¹ biomagnify in aquatic food webs. In addition, many metals do not bioaccumulate in aquatic food webs (i.e., tissue concentrations of some metals decrease with increasing trophic level). However, the scientific literature is somewhat contradictory on whether metals tend to result in secondary poisoning. Some studies suggest that metals can be quite toxic via food chain transfer (Dallinger et al. 1987, Woodward et al. 1994),

¹ This point refers to inorganic metal compounds, and not organometallic compounds such as methyl mercury.

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while others suggest that the diet contributes negligibly to metal toxicity (Macek et al. 1979, Hansen and Lambert 1987). With the exception of perhaps mercury and selenium, secondary poisoning by metals may largely be a site-specific issue.

Leland and Kuwabara (1985) state that the classic idea of biomagnification, developed from studies of DDT, does not hold for most metals. Macek et al. (1979) went a step further and questioned the importance of the food web as a pathway for accumulation of most chemicals. According to Macek et al. (1979), early investigators stressing the importance of food web transfer of chemicals were generally basing their hypotheses on studies with DDT. In addition, some researchers demonstrating the importance of food web transfer failed to factor in the quantitative significance of different exposure pathways. Macek et al. (1979) studied cadmium and several organic chemicals to determine the importance of the dietary contribution of a chemical to the body burden. The dietary contribution was only substantial for DDT, while for cadmium, the diet contributed to only 1.2 percent of the body burden in shrimp.

The limited bioavailability of inorganic forms of metals in food may explain why metals are generally not considered secondary poisons. It is generally assumed that higher residues of trace substances in the food chain should result in greater hazards to the consumer; however, studies have shown that there are a number of modifying factors that reduce the potential for adverse effects (Hansen and Lambert 1987). Absorption of metals from food is highly variable because of the variety of free and bound forms of the ions that are possible in food (Spacie and Hamelink 1985). In addition, competition between related elements for active transport sites is also variable. The following further discusses food chain transfer of metals and whether it is likely to result in secondary poisoning. For comparison, food chain transfer and secondary poisoning by certain organometallic and organic compounds are also discussed.

2.5.1 Metals and Inorganic Metallic Compounds

2.5.1.1 Cadmium

According to Suedel et al. (1994), there is little evidence to suggest that cadmium biomagnifies in aquatic systems. Ferard et al. (1983) examined the transfer of cadmium in an experimental food chain consisting of algae (Chlorella vulgaris), zooplankton (Daphnia magna), and fish (Leucaspias delineatus). Algae were exposed to one of four cadmium concentrations for 10 days, Daphnia were allowed to feed on the exposed algae for 20 days, and fish were allowed to feed on the Daphnia for 4 days. Algae exposed to concentrations of 10, 50, 100, and 250 µg/L accumulated cadmium to concentrations of 30, 92, 210, and 570 mg/kg dw, respectively. Cadmium concentrations in Daphnia were similar to or less than those in the algae they fed upon - 32, 44, 58, and 259 mg/kg dw at successively higher exposure concentrations. Despite the lower cadmium residues, however, Daphnia reproduction was impaired at all exposure levels. In the fish, cadmium concentrations were less than one mg/kg dw at all exposure levels. These results demonstrate that cadmium does not biomagnify and they suggest that cadmium concentrations may decrease with increasing trophic level, as demonstrated by cadmium concentrations in the algae and Daphnia. The even lower concentrations measured in the fish may simply be a function of the short exposure time over which fish were allowed to feed on contaminated Daphnia. The main point of this study is that cadmium concentrations appear to decrease with increasing trophic level.

47

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

April 2000 55-3690-001 (01) WURKLAND_IVOLIDATAworking\3690biogccumulation report2 (march 2000).doc

It should be noted that the toxicity in *Daphnia* observed by Ferard et al. (1983) does not necessarily imply that cadmium should be regarded as a secondary poison since the original cadmium concentrations to which algae were exposed are much greater than what would be considered environmentally relevant. Furthermore, cadmium concentrations in water were not measured, although cadmium was likely released from the algae into the water. Consequently, the observed toxicity in *Daphnia* may have been from a waterborne exposure. Further studies should be conducted at environmentally relevant concentrations to confirm whether it should be of concern.

As summarized by Rainbow (1989), certain pelagic seabirds contain extremely high concentrations of cadmium in their kidney and liver, and these levels appear to be natural in origin. A probable source of the cadmium is the diet and as a result, Rainbow (1989) evaluated cadmium concentrations in two Antarctic populations of the pelagic amphipod *Themisto gaudichaudii* and an Atlantic population of *T. compressa*. Cadmium concentrations in these amphipods are atypically high and do not appear to be of anthropogenic origin. In contrast to some studies, this study demonstrates that cadmium may be naturally bioaccumulated to high levels in some food webs and, as such, the potential for secondary poisoning with respect to hazard classification must be considered carefully.

There are a number of modifying factors that reduce the potential for biological effects due to metals in the diet. Cadmium, for example, interacts with many other nutritional elements and its bioavailability is influenced by diet, nutrition, and chemical species (Hansen and Lambert 1987). In short-term feeding studies, data indicate that cadmium bound to metallothionein is less bioavailable than cadmium salts (Hansen and Lambert 1987). This is consistent with the review of Spacie and Hamelink (1985) who suggest that the organically bound fraction of metal in food is relatively unavailable for uptake in the gut. Limited metal bioavailability in birds has also been observed. Intestinal uptake of cadmium in Japanese quail, for example, was dose-dependent and represented only about 0.4 to 2 percent of the dose (Furness 1996).

2.5.1.2 Copper

There is no evidence that copper biomagnifies in aquatic systems, although it does appear to be transferred through food chains (Suedel et al. 1994). As reviewed by Lewis and Cave (1982), copper accumulation in aquatic organisms at different trophic levels varies considerably and depends on several factors, including the physiological requirements of the organism, the source of copper, exposure duration, migration patterns, and chemical speciation.

No studies were identified that conclusively demonstrate copper results in secondary poisoning. Woodward et al. (1994) fed rainbow trout (*Oncorhynchus mykiss*) fry benthic invertebrates from the Clark Fork River, Montana for 91 days. The benthic invertebrates had elevated concentrations of copper, as well as elevated levels of arsenic, cadmium, and lead. This study demonstrated that dietary copper can be an important source for copper bioaccumulation in exposed fish, but it cannot be conclusively stated whether the observed toxicity was due to copper, since concentrations of other metals were elevated. The following discusses dietary toxicity studies in which fish were exposed to diets with only elevated copper concentrations.



Kamunde (1999) exposed rainbow trout to dietary copper concentrations of 11 (control), 300, and 1,000 mg/kg for 28 days. The results suggested that the gut appears to present a strong barrier to internal uptake of elevated dietary copper. Gut tissue concentrations increased slightly, but significantly, in fish fed 300 mg/kg copper and approximately an order of magnitude in fish fed 1,000 mg/kg copper. No effects were observed on growth of the fish at these dietary copper levels. It appears that elevated dietary copper levels alter the energy budget by expending more energy toward copper regulation, but a higher dietary intake rate counteracted these effects and the growth rates remained similar to the controls (Kamunde 1999).

As another example, Mount et al. (1994) fed rainbow trout fry enriched with copper for 60 days. Dietary copper concentrations of 660 and 800 mg/kg dw had no effect on fish growth, but resulted in approximately 30 percent mortality. These concentrations are higher than those measured in invertebrates in the Clark Fork River, Montana, a location with extremely elevated metals concentrations. The authors hypothesize that the observed toxicity may actually have been due to waterborne copper. If 20 percent of the dietary copper was lost to the water ($20 \mu g/L$), and added to the level of copper already in the water (23 μ g/L), the waterborne copper concentration would reach a level that is acutely toxic to trout (Mount et al. 1994). Moreover, Mount et al. (1994) note that toxicity in other studies have not been observed at similar dietary levels, and that in one study, 30 percent mortality was not observed until the dietary copper concentration reached 3,088 mg/kg dw. As such, this study further supports that copper is unlikely to cause secondary poisoning at environmentally relevant concentrations. Miller et al. (1993) fed rainbow trout (O. mykiss) a synthetic trout diet containing either 13 or 684 mg/kg copper. The fish fed the 13 mg/kg diet were also exposed to aqueous copper concentration of either 5, 32, 55, or 106 µg/L, while fish fed the 684 mg/kg diet were exposed to aqueous copper concentrations of either 13, 38, 62, or 127 μ g/L. The experiment was conducted for 42 days. None of these combinations of dietary and waterborne copper concentrations affected trout survival or growth.

2.5.1.3 Lead

According to reviews of Eisler (1988) and Suedel et al. (1994), there is no evidence that lead biomagnifies in higher trophic levels of either freshwater or marine food webs. As reviewed by Demayo et al. (1982), dietary lead may be virtually unavailable to fish such as rainbow trout. This is supported by the studies summarized below.

Simulating an aquatic food chain in the laboratory, Vighi (1981) exposed *Selenastrum capricornutum* (green alga), *Daphnia magna* (zooplankton), and *Poecilia reticulata* (guppy) to lead nitrate for four weeks. Lead concentrations in guppies were three to four times greater in fish exposed to lead via water and food than in fish exposed to lead via water only. However, lead residues were still low (3.2 to 7.2 mg/kg ww, assuming a moisture content of 80 percent) and found to decrease with increasing trophic level. Given that lead residues were low in fish and found to decrease with increasing exposure level, this study provides evidence to suggest that lead should not be of concern as a secondary poison.

In a field study, Henny et al. (1991) similarly observed decreasing lead concentrations with increasing trophic level. Henny et al. evaluated fish and ospreys in a portion of the Coeur d'Alene River (Idaho) contaminated with high levels of lead. Whole fish collected along the river had

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

49

April 2000 55-3690-001 (01) WCBKLAND_IWOLIVDATAtworking\3690bioaccumulation report2 (march 2000).doc

elevated lead concentrations compared to fish collected at intermediate or reference areas. Mean whole body lead concentrations in fish from the river ranged from 0.75 mg/kg ww in largemouth bass (*Micropterus salmoides*) to 21.6 mg/kg ww in brown bullhead (*Ictalurus nebulosus*). Blood levels in ospreys were inversely related to δ -aminolevulinic acid dehydratase (ALAD) activity, indicating that they had recently been exposed to lead (decreased ALAD activity is an indicator of exposure, but not of effects). However, lead levels in ospreys were lower than in fish, presumably because bones and hard parts of the fish are not ingested and this is where lead tends to accumulate (Henny et al. 1991). Moreover, despite elevated lead concentrations occurring in river sediments and bioaccumulating in fish, there was no evidence of secondary poisoning of lead through the food chain from sediments because no effects on osprey reproductive performance along the river were observed.

2.5.1.4 Nickel

There is also no evidence that nickel biomagnifies in aquatic food webs (Suedel et al. 1994). Watras et al. (1985) studied nickel accumulation in *Daphnia magna* fed nickel-enriched algae and non-enriched algae (*Scenedesmus obliques*) for 13 days. *Daphina* were exposed to nickel via algae only, water only, or a combination of algae and water. *Daphnia* exposed to nickel via algae only accumulated nickel to a concentration of only 29 μ g/kg ww, while *Daphnia* exposed to nickel via water only accumulated a much higher nickel concentration of 681 μ g/kg ww. There was no indication that these levels resulted in effects to *Daphnia*. This study, therefore, demonstrates that nickel is not transferred significantly between trophic levels (i.e., through ingestion), nor does it appear to result in secondary poisoning (at least at lower trophic levels). In a field study reported by Mathis and Cummings (1973), nickel concentrations were also found to decrease with increasing trophic level in a food web characterized by clams, oligochaetes, omnivorous fish, and carnivorous fish, again demonstrating that food chain transfer of nickel is minimal, as is its potential for secondary poisoning.

2.5.1.5 Zinc

As for the other metals discussed above, there is no evidence that zinc biomagnifies in aquatic systems (Suedel et al. 1994). Given that zinc is an essential element, many organisms are known to accumulate zinc to high levels. Elevated accumulation rates may sometimes be mistaken as trophic transfer (Suedel et al. 1994). As discussed above, it appears that the organically bound fraction of metal in food is relatively unavailable for uptake in the gut. This is also confirmed based on data for zinc. In the sunfish (*Lepomis gibbosus*), for example, more zinc was accumulated from an artificial diet than from a natural diet of snails containing the same levels of zinc (Merlini et al. 1976). No studies were identified that explicitly assessed the potential for zinc to cause secondary poisoning.

2.5.1.6 Metal Mixtures

According to Dallinger et al. (1987), metals can reach concentrations in tissues that result in secondary poisoning even if they do not bioaccumulate to high levels or biomagnify. Woodward et al. (1994) fed rainbow trout fry (*O. mykiss*) invertebrates from the Clark Fork River, Montana that had large concentrations of metals. The guts of the invertebrates were not purged, so the metal

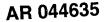
April 2000 55-3690-001 (01) WARKLAND_IVOLIDATAImorking\3690biaaccumulation report2 (march 2000).doc concentrations in the invertebrates were based on accumulated metal in tissue plus metals bound to sediment in the gut. The mean concentrations of aluminum, arsenic, cadmium, copper, lead, and zinc were 1,759, 43.1, 3.12, 381, 32.7, and 528 mg/kg dw, respectively. Fry were also simultaneously exposed to water solutions with non-detectable levels of metals, solutions simulating typical metal levels in the river - cadmium, copper, lead, and zinc concentrations were 1.1, 12, 3.2, and 50 μ g/L, respectively, or double these aqueous concentrations. The fry fed invertebrates with high metals levels had significantly reduced survival and growth, regardless of the aqueous metal concentrations to which they were exposed.

In a second study with a similar study design, early life stages of rainbow trout (*O. mykiss*) and brown trout (*Salmo trutta*) were exposed to aqueous metals in simulated Clark Fork water and dietary metals from invertebrates collected from the river (Woodward et al. 1995). The aqueous metal concentrations were the same as those tested in Woodward et al. (1994), while metal concentrations in invertebrates were lower, with the exception of zinc. Specifically, mean arsenic, cadmium, copper, lead, and zinc concentrations in invertebrates were approximately 19, <0.26, 174, 15, and 648 mg/kg dw. Exposure to any combination of aqueous and dietary metal concentrations did not have any effects on survival; however, effects on growth were observed. In brown trout, for example, exposure to aqueous metals only resulted in a 25 percent reduction in growth relative to fish exposed to reference water and diet, a 40 percent reduction in fish exposed to dietary metals. Similar reductions in growth were observed in rainbow trout exposed to both aqueous and dietary metals. Similar reductions in growth were observed in rainbow trout exposed to both aqueous and dietary metals. The Woodward et al. (1994, 1995) studies suggest that metal residues can result in secondary poisoning.

Mount et al. (1994) exposed rainbow trout (*O. mykiss*) to live diets (*Artemia* sp.) enriched with arsenic, cadmium, copper, lead, and zinc. No effects were observed on survival, weight, or length after 60 days of exposure to any of the treatments. The highest treatment contained dietary arsenic, cadmium, copper, lead, and zinc concentrations of 63, 21, 250, 82, and 740 mg/kg dw, respectively. These results are inconsistent with those reported by Woodward et al. summarized above, in which the trout diets were based on field-exposed invertebrates.

The above studies provide evidence that metals may cause secondary poisoning, although the evidence is somewhat conflicting. As discussed above, organisms have been observed to tolerate much higher metals concentrations in the laboratory. The differences in sensitivities observed in the Woodward et al. studies and laboratory studies discussed above is unclear. It may be a function of the difference in bioavailabilities between naturally and artificially incorporated metals, but there even seems to be conflicting evidence on this point. Merlini et al. (1976) observed that sunfish accumulated more zinc from an artificial diet than from a natural one, while Harrison and Curtis (1992) reported that environmentally contaminated natural foods have a greater absorption efficiency that surficially contaminated artificial diets. This is different than for some organometallics (e.g., methyl mercury, and organoselenium) where secondary poisoning has been documented in both the field and laboratory.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds



2.5.2 Organometallic Compounds

As the name suggests, an organometallic compound consists of a metal and an attached organic moiety. Organometallic compounds may be formed naturally in the environment (e.g., methylmercury, organoselenium) or from anthropogenic sources (e.g., organolead, tributyltin). Organometallic compounds tend to have greater bioaccumulation potential than inorganic metallic compounds, and some are known to biomagnify. Some representative organometallic compounds are discussed below for comparison with inorganic metals.

2.5.2.1 Naturally-Derived Organometallics

Methvimercury

Methylmercury is produced naturally in the environment via microbial methylation of inorganic mercury (II) (Weiner and Spry 1996) and is known to biomagnify in aquatic food webs (Biddinger and Gloss 1984, Eisler 1987, Sadiq 1992, Watras and Bloom 1992, Mason et al. 1995). In fish, it is estimated that greater than 90 percent of the methylmercury accumulated is through the diet (Wiener and Spry 1996). The high assimilation efficiency of methylmercury in fish is probably greater than 65 to 80 percent, while the absorption rate in mice has been found to be even higher, approximately 98 percent (Clarkson 1971). Given its high assimilation efficiency in fish, methylmercury rapidly penetrates and is cleared from the gut, binds to red blood cells, and is rapidly transported to all organs. In addition to its high assimilation efficiency, methylmercury tends to biomagnify in aquatic food webs because it is eliminated very slowly in fish relative to its rate of uptake (McKim et al. 1976). Moreover, unlike many inorganic metals, including inorganic mercury, methylmercury does not induce metallothionein or bind to existing metallothionein with much affinity (Wiener and Spry 1996). Based on its biochemical properties, its propensity to biomagnify, and toxicological studies in the laboratory and field, mercury in its methylated form should be considered a secondary poison. **Organoselenium**

In lentic water bodies with high biological activity, selenium is transferred through the food web as organoselenium compounds. For example, organoselenium compounds can bioaccumulate to levels in aquatic invertebrates that are nontoxic to the invertebrates themselves, but toxic to the shorebirds that feed upon them (Ohlendorf et al. 1986). Similar to methyl mercury, absorption of organoselenium in the gut of experimental animals has been shown to be high (i.e., 95-97 percent in rats [Thomson and Stewart 1973]). There is no evidence, however, that organoselenium compounds biomagnify in the food web (Sandholm et al. 1973, Suedel et al. 1994). Besser et al. (1993) exposed a simulated food chain consisting of algae (*Chlamydomona reinhardtii*), daphnids (*Daphnia magna*), and bluegill sunfish to organic and inorganic selenium. Except at very low exposure concentrations, daphnids and bluegill did not accumulate selenium concentrations greater than those in their diet. However, organoselenium has been shown to be a secondary poison to fish and shorebirds (Finley et al. 1985, Ohlendorf et al. 1986).

Organic Arsenicals

The propensity for organic arsenic compounds to biomagnify or cause secondary poisoning in aquatic biota has not been extensively studied. It is generally considered that organic arsenic

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds 52

April 2000 55-3690-001 (01) WKIRKLAND_IVPOLIDATA/workingU690bioaccumulation report2 (march 2000).doc



compounds do not biomagnify because they are easily excreted (Biddinger and Gloss 1984). Cockell and Hilton (1988) exposed juvenile rainbow trout (*O. mykiss*) to dietary organic arsenic (as dimethylarsinic acid or arsanilic acid) concentrations of 200, 400, 800, and 1,600 mg/kg for eight weeks. None of these dietary levels had any significant effects on growth or survival. The highest concentration tested exceeded 1,000 times the background level in the control diet (Cockell and Hilton 1988). The arsenic data are limited, but it is important to note that not all organometallic compounds behave similarly with regards to biomagnification potential and secondary poisoning. As such, they should be classified separately on a compound-by-compound basis.

2.5.2.2 Anthropogenically-Derived Organometallics

It is beyond the scope of this report to provide a detailed review on all organometallic compounds. The propensity for methyl mercury and organoselenium compounds to result in secondary poisoning was summarized in the previous section since it has been well document in both laboratory and field studies. Other organometallic compounds, particularly those of anthropogenic origin (e.g., tetraethyllead, organotins), have not been well studied in food webs. It should not be assumed that these compounds behave like methyl mercury or organoselenium in the environment. In addition, it should not be assumed that individual compounds within an organometallic group will behave the same. Tributyltin, for example, behaves much differently and has a much different toxicity potential than other organotins (e.g., monobutyltin, dibutyltin, octyltins). As a result, these compounds need further review before interpretation can be provided on their potential to bioaccumulate and result in secondary poisoning.

2.5.3 Conclusions on Secondary Poisoning

Limited bioavailability from dietary sources is probably the key parameter that explains why most conclude that inorganic forms of metals do not result in secondary poisoning. It has been demonstrated in both laboratory and field studies that concentrations of some metals decrease with increasing trophic level. Even though some aquatic biota may bioaccumulate metals to levels higher than those to which they were exposed, these metals tend to have limited bioavailability to the organisms that feed upon them. Because many organisms have developed strategies that allow for the naturally high bioaccumulation of some metals in nontoxic forms, it also suggests that there is a mechanism by which consumers are not poisoned by feeding on these organisms. Although no studies on this topic are known, it suggests that detoxified metal granules are probably not bioavailable to biota in higher trophic levels. As discussed above, some studies have suggested that metals bound to metallothioneins are also not bioavailable to upper trophic level biota.

The majority of the data indicate that inorganic metal compounds are not secondary poisons. A limited number of studies (e.g., Woodward et al. 1994, 1995) in which fish were fed field-exposed invertebrates indicate that secondary poisoning may be an issue in some site-specific situations. However, with any field study, or study with a field-based component, there may be unknown confounding factors that influence the results. The results have yet to be duplicated in laboratory-based food chains. On the other hand, the naturally-derived organometallics methylmercury and organoselenium have been documented in both field and laboratory studies to result in secondary poisoning.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

53

April 2000 55-3690-001 (01) WKIRKLAND_IVOLIDATAWorking\3690bioaccumulanon report2 (march 2000).doc



3. CONCLUSIONS

As summarized by Chapman (1996), hazard classification of metals and metal compounds should be determined based on three specific questions:

- 1.) Is a substance bioavailable such that adverse environmental effects may occur?;
- 2.) If bioavailable, is a substance likely to cause short-term adverse effects to aquatic organisms?; and
- 3.) If bioavailable, but not exhibiting short-term adverse effects to aquatic organisms, is a substance likely to cause long-term adverse effects to aquatic organisms?

As demonstrated in this report, none of these questions are addressed by using BCFs for metals or inorganic metal compounds. Accordingly, two major questions were addressed in this report with regards to metals and metal compounds: (1) Is there a direct relationship between bioaccumulation potential and direct toxicity? In other words, do the more bioaccumualtive metals tend to be more toxic with increasing bioaccumulation potential?; and (2) Is there a relationship between bioaccumulation between bioaccumulation potential and secondary poisoning or biomagnification of metals? The answers to each of these questions are summarized below.

Is there a relationship between bioaccumulation potential and direct toxicity?

"It is like stating the obvious: trace metals can be accumulated by freshwater invertebrates (Timmermans 1993)." Invertebrates, and all aquatic organisms, must control intracellular trace metals concentrations that are essential for life. As such, they have developed various mechanisms that allow them to (1) acquire (i.e., accumulate) sufficient amounts of trace metals from low ambient conditions, and (2) regulate any influx of essential trace elements beyond metabolic requirements or non-essential trace elements that pose potential toxicity at low concentrations (Phillips and Rainbow 1989). The regulatory strategies of aquatic organisms range from active regulation (i.e., active excretion of excess metal) to storage (i.e., excess metals are stored in detoxified forms). For simplicity, these two extremes in regulatory strategies are discussed further in order to summarize the key points from this report.

Some organisms can regulate certain metals, such that all metal that is accumulated in excess of its metabolic requirements is excreted (Rainbow 1996). As the external metal concentration increases, the regulatory mechanism is overwhelmed and net accumulation occurs (i.e., the uptake rate exceeds the excretion rate). In organisms such as these, the bioaccumulation potential of metals cannot be described by individual BCFs. The organism is able to maintain a fairly constant tissue concentration of essential metals over a wide range of metal exposure concentrations. As a result, the BCF is dependent on the water concentration to which the organism is exposed – the bioaccumulation potential of a metal may appear extremely high at a low water concentration, but negligible at a high water concentration. In addition, because these organisms regulate metals through active uptake and excretion and do not have well developed mechanisms for storing excess metal, these organisms are unable to accumulate substantial amounts of metal before toxicity results.

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

April 2000 55-3690-001 (01) \KIRKLAND_IVOLIDATA\working\690bioaccumulation report2 (march 2000).doc At the other end of the spectrum, an organism may sequester all metal that is accumulated with no significant excretion (Rainbow 1996). For these organisms, the metal is stored in a detoxified form. Although such an organism may have a high BCF, it also has a storage mechanism that renders the metal non-toxic. Since metals are stored in non-toxic forms, the high bioaccumulation potential in these organisms, of course, has no relationship to the toxic potential of the metal.

Many studies are available in the scientific literature demonstrating the lack of a relationship between bioaccumulation potential and direct metal toxicity. This report also provided multiple analyses demonstrating the lack of a relationship between bioaccumulation and toxicity. For example, the range in BCFs for cadmium and zinc over multiple species is almost identical despite cadmium being many times more toxic than zinc. Lastly, analyses of species sensitivity distributions for multiple metals suggest that toxicity is partially a function of an organism's regulatory mechanism, not its bioaccumulation potential. In fact, based on the analyses provided in this report, it is more likely that an inverse relationship exists between bioaccumulation potential and direct toxicity.

Is there a relationship between bioaccumulation potential and secondary poisoning?

Secondary poisoning results when an organism is adversely affected by a substance that has accumulated in its food items. Substances that biomagnify or bioaccumulate in food webs often are considered to have the potential to cause secondary poisoning. For metals, however, there is little evidence to suggest that inorganic metals biomagnify in aquatic food webs. Leland and Kuwabara (1985) state that the classic idea of biomagnification is mainly developed from studies of DDT, but does not hold for most metals. In addition to the general lack of biomagnification potential for metals, it has been shown that several metals do not bioaccumulate appreciably in aquatic food webs. Cadmium, lead, and nickel concentrations in tissue have both been shown to decrease with increasing trophic level (Vighi 1981, Henny et al. 1991, Ferard et al. 1983, Mathis and Cummings 1973).

It is important to note, however, that although biomagnification of metals does not occur and the bioaccumulation potential of many metals in aquatic food webs is low. There is some field evidence that metal concentrations can be bioaccumulated to levels high enough to induce secondary poisoning (e.g., Woodward et al. 1994). As mentioned before, these studies have not been validated in the laboratory-based food chains to eliminate confounding factors. However, given these data, further research is necessary to resolve the importance of dietary exposure in assessing the hazard of inorganic metals and metal compounds.

In summary, bioaccumulation is not an appropriate parameter for hazard classification of metals and inorganic metal compounds because (1) many organisms naturally bioaccumulate metals to high levels, (2) it is not possible to estimate the bioaccumulation potential of metals in many organisms because BCFs tend to be dependent on exposure concentration, (3) bioaccumulation potential cannot be related to direct toxicity, and (4) bioaccumulation potential cannot be related to the potential for secondary poisoning. Given that bioaccumulation potential of metals cannot be related to direct toxicity or secondary poisoning, it should not be used as a parameter in hazard classification of metals.

55

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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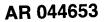
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Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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APPENDIX A

DATABASE OF BIOCONCENTRATION FACTORS (BCFs)

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		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Type	Type	(days)	Tissue		(µg/kg-wet)	(µg/L)	BCF	Reference
Aluminum	Algae Usterionella japonica)	Aleae	SW	25	Cells	1750000	175000	1800	6 7 0	Riley and Rath 1071
Aluminum	Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	307000	30700	1800	17.1	Rilev and Roth 1971
Aluminum	Algae (Chlorella salina)	Algae	ΝS	25	Cells	118000	11800	1800	6.6	Rilev and Roth 1971
Aluminum	Algae (Dunaliella primolecta)	Algae	ΜS	25	Cells	.289000	28900	1800	16.1	Rilev and Roth 1971
Aluminum	Algae (Dunaliella tertiolecta)	Algae	ΝS	25	Cells	160000	16000	1800	8.9	Riley and Roth 1971
Aluminum	Algae (Hemiselmis brunescens)	Algae	ΝS	25	Cells	55000	55000	1800	30.6	Riley and Roth 1971
Aluminum	Algae (Hemiselmis virescens)	Algae	ΝS	25	Cells	169000	16900	1800	9.4	Riley and Roth 1971
Aluminum	Algae (Heteromastix longifillis)	Algae	ΝS	25	Cells	735000	73500	1800	40.8	Riley and Roth 1971
Aluminum	Algae (Micromonas squamata)	Algae	ΝS	25	Cells	225000	22500	1800	12.5	Riley and Roth 1971
Aluminum	Algae (Monochrysis lutheri)	Algae	ΜS	25	Cells	275000	27500	1800	15.3	Riley and Roth 1971
Aluminum	Algae (Olisthodiscus luteus)	Algae	SW	25	Cells	358000	35800	1800	19.9	Riley and Roth 1971
Aluminum	Algae (Phaeodactylum tricornutum)	Algae	SW	25	Cells	490000	49000	1800	27.2	Riley and Roth 1971
Aluminum	Algae (Pseudopedinella pyriformis)	Algae	SW	25	Cells	478000	47800	1800	26.6	Rilev and Roth 1971
Aluminum	Algae (Stichococcus bacillaris)	Algae	SW	25	Cells	255000	25500	1800	14.2	Riley and Roth 1971
Aluminum	Algae (Tetraseimis tetrathele)	Algae	SW	25	Cells	425000	42500	1800	23.6	Rilev and Roth 1971
Aluminum	Brook trout (Salvelinus fontinalis)	Fish	FW	30	WB	I	12000	242	80	Cleveland et al. 1986
Aluminum	Brook trout (Salvelinus fontinalis)	Fish	FW	30	WB	I	33000	242	136	Cleveland et al. 1986
Arsenic (III)	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	ł	520	130	4.0	Barrows et al. 1980
Arsenic (III)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	21	WB	16400	3000	2950	1.0	Dixon and Sprague 1981
Arsenic (III)	Cladoceran (Daphnia magna)	Invert	FW	21	WB	48500	9700	970	10.0	Spehar et al. 1980
Arsenic (III)	Cladoc er an (Daphnia magna)	Invert	FW	21	WB	21024	4204.8	96	43.8	Spehar et al. 1980
Arsenic (111)	Eastern oyster (Crassostrea virginica)	Invert	ΝS	112	Soft parts	I	1	I	350	USEPA 1985a
Arsenic (III)	Snail (Helisoma campanulatum)	Invert	FW	28	WB	80000	8000	961	8.3	Spehar et al. 1980
Arsenic (III)	Snail (Helisoma campanulatum)	Invert	FW	28	WB	27000	2700	88	30.7	Spehar et al. 1980
Arsenic (III)	Snail (Stagnicola emarginata)	Invert	FW	28	WB	3100	310	88	3.5	Spehar et al. 1980
Arsenic (III)	Snail (Stagnicola emarginata)	Invert	FW	28	WB	15000	1500	961	1.6	Spehar et al. 1980
Arsenic (III)	Stonelly (Pteronarcys dorsata)	Invert	FW	28	WB	1000	100	88	1.1	Spehar et al. 1980
Arsenic (III)	Stonefly (Pteronarcys dorsata)	Invert	FW	28	WB	43000	4300	961	4.5	Spehar et al. 1980
Arsenic (V)	Fathcad minnow (Pimephales promelas)	Fish	FW	30	WB	I	I	ł	e	USEPA 1985a
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	77	WB	I	200	01	20	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	11	WB	I	300	1390	0.22	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	11	WB	1	1000	16250	0.06	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	77	WB	I	100	01	10	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	11	WB	I	250	1440	0.17	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	77	WB	I	800	8360	0.10	McGeachy and Dixon 1990
Arsenic (V)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	11	WB	I	1750	18050	0.10	McGeachy and Dixon 1990
Arsenic (V)	Cladocetan (Daphnia magna)	Invert	FW	21	WB	20000	4000	1000	4.0	Spehar et al. 1980
Arsenic (V)	Cladoceran (Daphnia magna)	Invert	FW	21	WB	50000	10000	001	100.0	-
Arsenic (V)	Grass shrimp (Palaemonetes pugio)	Invert	ΜS	28	WB	6120	1224	0.71	1723.9	
Arsenic (V)	Grass shrimp (Palaemonetes pugio)	Invert	ΜS	28	WB	5750	1150	9.67	118.9	-
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AR 044657

November 5, 1999

1 - V

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

		Organism	1210 14			115500	1 ISSUC			
Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(J/gr)	BCF	Reference
Arsenic (V)	Grass shrimp (Palaemonetes pugio)	Invert	SW	28	WB	5160	1032	24.6	42.0	Lindsay and Sanders 1990
Arsenic (V)	Snail (Helisoma campanulatum)	Invert	FW	28	WB	8800	880	68	9.9	Spehar et al. 1980
Arsenic (V)	Snail (Helisoma campanulatum)	Invert	FW	28	WB	28000	2800	196	2.9	Spchar et al. 1980
Arsenic (V)	Snail (Stagnicola emarginata)	Invert	FW	28	WB	3100	310	88	3.5	Spehar et al. 1980
Arsenic (V)	Snail (Stagnicola emarginata)	Invert	FW	28	WB	14000	1400	196	1.5	Spehar et al. 1980
Arsenic (V)	Stonefly (Pteronarcys dorsata)	Invert	FW	28	WB	12000	2400	91.6	26.2	Spehar et al. 1980
Arsenic (V)	Stonelly (Pteronarcys dorsata)	Invert	FW	28	WB	31000	6200	973	6.4	Spehar et al. 1980
Beryllium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	5130	270	19.0	Barrows et al. 1980
Cadmium	Diatom (Ditylum brightwellii)	Algae	MS	14	Cells	20000	2000	75	26.7	Canterford et al. 1978
Cadmium	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	23000	2300	150	15.3	Canterford et al. 1978
Cadmium	Diatom (Ditylum brightwellii)	Algae	ΜS	14	Cells	24000	2400	300	8.0	Canterford et al. 1978
Cadmium	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	21000	2100	450	4.7	Canterford et al. 1978
Cadmium	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	5000	5000	600	8.3	Canterford et al. 1978
Cadmium	NW salamander <i>Umbystoma gracile</i>)	Amphibian	FW	24	WB	I	1620	48.9	33.1	Nebeker et al. 1995
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	330	Gill	ł	34000	31	1096.8	Eaton 1974
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	330	Kidney	I	188000	31	6064.5	Eaton 1974
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	330	Liver	I	201000	31	6483.9	Eaton 1974
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	40	0.03	1333.3	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	100	0.8	125.0	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	1	140	1.8	77.8	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	1	200	2.2	90.9	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	240	3.6	66.7	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	ł	290	4.4	63.9	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	360	5.2	69.2	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	510	8.4	60.7	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	1	0	0.02	0.0	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	100	2.8	35.7	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	ł	250	6.2	40.3	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FΨ	28	WB	I	360	7.7	46.8	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	750	13.2	56.8	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	1	009	16.1	37.3	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	650	19.7	33.0	Cope et al. 1994
Cadmium	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	1400	32.3	43.3	Cope et al. 1994
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Gill	909	120	0.06	2000.0) Benoit et al. 1976
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Gill	3000	009	0.5	1200.0) Benoit et al. 1976
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Kidney	1400	280	0.06	4666.7	-
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Kidney	11000	2200	0.5	4400.0	Denoit et al. 1976
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Liver	300	3	0.06	1000.0	D Benoit et al. 1976
Cadmium	Brook trout (Salvelinus fontinalis)	Fish	FW		Liver	3000	009	0.5	1200.0	D Benoit et al. 1976

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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Reference	Between at 1070	Defeate at all 1979	Debate of al. 1979				Koberts et al. 1979	Roberts et al. 1979	Roberts et al. 1979	Roberts et al. 1979	Koberts et al. 19/9	Westernhagen et al. 1980	Noel-Lambot and Bouquegneau 1977	Noel-Lambot and Bouqueeneau 1977	Noel-Lambot and Bougheemean 1977	Noel-Lambot and Rougiesen 1977	Norl-I ambot and Bournessian 1977	Noel-I ambot and Bouquegreau 1977	Station and 1079	Spectral of all 1978	Smehar at al 1078	Spehar et al. 1078	Souther at al 1079	Openiar of all 1970 Stather at al 1079			Kistalioglu et al. 1996	Kislalioglu et al. 1996	Kislalioglu et al. 1996	Kislatioglu et al. 1996	Kislatiochn et al. 1006	Kislaliogiu et al. 1996										
BCF	1 21	()) ())				0.0	5.95 2 2	3.5	42.2	0.4		4.6	8.3 2.02:	1.801	7.70	c.o	10.8	10.7	23.2	3.1	51.5	15.4	123.1	36.9	. .	3.1	10.8	4 3	400.0	800.0	1860 5	\$07.9	3 7 6	5.58 B		0.112	2600.0	426.0	2840.0	686.0	2300.0	560.0
Water (µg/L)	5	: 5	: 5	: 5	5 6	5 5	5 5	2 5	1	12	17	9 . .	44.C	44.C		44.C	\$	5.44 2.5	5.44	001	130	130	130	130	130	130	130	130	ī	0.1	4.3	6.3	~		. X	7	c.u	Ś	0.5	••	0.5	s
Tissue (µg/kg-wet)	440	1780		, c	2	0201	2001	44	1140	2 8	2	7.67	C4	4.14C	0.000	4.00	<u>ک</u>	28	126.4	400	6700	2000	16000	4800	200	400	1400	560	40	80	8000	3200	1200	2600	17500	00071	10001	2130	1420	3430	1150	2800
Tissue Tissue (μg/kg-dry) (μg/kg-wet)	2200	8900	05	-	480	UUE S		6700		90	261	975	C22	10.67		706	100	067 .	632	I	I	ł	I	I	1	I	I	I	200	400	40000	16000	16000	28000		ł	I	I	I	i	I	ł
Tissue	Gills	Gills	Heart	Heart	Kidnev	Kidney	I iver		Colore	Spleen	Backhone	Derrel for		l iver	Musche (fillet)	Otolithe	Skin (dorral)		Skin (ventral)	Bile	Digestive tract	Gill filaments	Kidneys	Liver	Muscles	Skin	Spleen	WB	WB	WB	WB	WB	WB	WB	WB			5	Kidney	Kidney	Liver	Liver
Duration (days)	14	8	14	8	14	06	14	: 5	2 2	± 8	8	8	2	8	8	8	8	2 2	r :	8 (99	60	60	8	99	60	8	99	100	001	001	001	001	001	32	201		601	60	601	109	601
Water Type	FW	FW	FW	FW	FW	ΕW	ΕW	FW.	: n	FW	MS	MS	ms	MS	MS	MS	MS		M O	MO	N S	SW	SW	SW	SW	SW	SW	SW	FW	FΨ	FW	FW	FW	FW	FW	ΕM		× 1	FW	FW	FW	FW
Organism Type	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Eich.	Fish	Fish	Fich	Fish	Fish	Fish	Fish	Fish	Fieh.			FISH	F 15h	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	101.1		Fish	Fish	Fish	Fish
Species	Brown trout (Sa <i>lmo trutta</i>)	Brown trout (Salmo trutta)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Dab (Limanda limanda)	Eel (Anguilla anguilla)	Eel (Anouilla anouilla)	Eel (Anouillo anouillo)		cci (Anguita anguita)	Eel (Angulia anguila)	Eel (Anguilla anguilla)	Ecl (Anguilla anguilla)	Eel (Anguilla anguilla)	Eel (Anguilla anguilla)	Flagfish <i>Vordanella floridae</i>)	Flagfish (Jordanella floridae)	Flaglish (Jordanella floridae)	Flagfish Vordanella floridae)	Flagfish Vordanella floridae)	Flagfish (Jordanella floridae)	Guppy (Poecilia reticulatal)	Lake charr (Salvelinus namaycush)	Lake chart (Salvelinus nomovcush)	l aka charr (Columina management)	t -trtrtr-tr-tr-tr-tr-tr-tr-tr-tr-tr-t	Lake chair (Saivelinus namaycush)	Lake chart (Salvelinus namaycush)	Lake charr (Salvelinus namaycush)								
MetaVMetalloid	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmiun	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium		Caumium C-1	Caomium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Cadmina		Cadmium	Cadmium	Cadmium

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Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

AR 044659

November 5, 1999

8 - Y

SpeciesType <t< th=""><th></th><th></th><th>O gamman</th><th>W alc</th><th>Duration</th><th></th><th>IIISUC</th><th>1 155UC</th><th></th><th></th><th></th></t<>			O gamman	W alc	Duration		IIISUC	1 155UC			
Rations true (<i>Decer)media</i> mytkin)FichFW14Cifk290039096444Rations true (<i>Decer)media</i> mytkin)FishFW90Cifk710039096444Rations true (<i>Decer)media</i> mytkin)FishFW90Cifk710039096444Rations true (<i>Decer)media</i> mytkin)FishFW90Cifk710039096444Rations true (<i>Decer)media</i> mytkin)FishFW455Kideny39009244Rations true (<i>Decer)media</i> mytkin)FishFW455Kideny39009244Rations true (<i>Decer)media</i> mytkin)FishFW455Kideny39009134Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny39003403911.1Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny3901341347.16Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny390134137.16Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny390134137.16Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny390134137.16Rations true (<i>Decer)media</i> mytkin)FishFW86Kideny390134137.16Rations true (<i>Dec</i>	Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-wet)	(hg/L)	BCF	Reference
Rainbow tord (<i>Decer)media</i> mydis)FiaFW90Gills1710336033400Rainbow tord (<i>Decer)media</i> mydis)FiaFW90GillsFW9011102292.48Rainbow tord (<i>Decer)media</i> mydis)FiaFW43Kidney37907.36192.368Rainbow tord (<i>Decer)media</i> mydis)FiaFW453Kidney379007.362.368Rainbow tord (<i>Decer)media</i> mydis)FiaFW453Kidney379007.362.368Rainbow tord (<i>Decer)media</i> mydis)FiaFW453Kidney39900.472.3632.3648Rainbow tord (<i>Decer)media</i> mydis)FiaFW560Kidney399007.30102.3648Rainbow tord (<i>Decer)media</i> mydis)FiaFW560Line399007.3013613713716Rainbow tord (<i>Decer)media</i> mydis)FiaFW560Line1300131317136131317136Rainbow tord (<i>Decer)media</i> mydis)FiaFW560Line1300131317136131317136Rainbow tord (<i>Decer)media</i> mydis)FiaFW560Line130013131713171361313171317136 <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>14</td> <td>Gills</td> <td>29000</td> <td>5800</td> <td>6</td> <td>644.4</td> <td>Roberts et al. 1979</td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	14	Gills	29000	5800	6	644.4	Roberts et al. 1979
Relations true (<i>Concrymedus arylis</i>)FailF.W14Her1102292.4RRainbow true (<i>Concrymedus arylis</i>)FailF.W43K.dany	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	66	Gills	17700	3540	01	354.0	Roberts et al. 1979
Reinhow troat (<i>Decrybrindum arylist</i>)EichF.W90Her1002010023920Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453K.diney939003.32011.1Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453K.diney93003.42011.1Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453K.diney93003.42011.1Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453K.diney93003.42013.1Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line93003.42013.1Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line11002.32.304.8Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line11003.42.304.8Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line11003.42.304.8Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line1200133.312.23Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line2.300133.312.2Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line2.300133.312.2Rainhow troat (<i>Decrybrindum arylist</i>)EichF.W453Line <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>14</td> <td>Heart</td> <td>011</td> <td>22</td> <td>6</td> <td>2.4</td> <td>Roberts et al. 1979</td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	14	Heart	011	22	6	2.4	Roberts et al. 1979
Relation trans (<i>Concription anylas</i>) Eich FW 180 (<i>Kiney</i>) - 179 0 179 C Rainbow trans (<i>Concription anylas</i>) Eich FW 455 (<i>Kiney</i>) - 900 0.1 731 111 18 Rainbow trans (<i>Concription anylas</i>) Eich FW 455 (<i>Kiney</i>) - 900 0.1 731.016 911.11 8 Rainbow trans (<i>Concriptiona anylas</i>) Eich FW 455 (<i>Kiney</i>) - 900 0.1 730.01 911.1 8 <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>8</td> <td>Heart</td> <td>100</td> <td>20</td> <td>10</td> <td>2.0</td> <td>Roberts et al. 1979</td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	8	Heart	100	20	10	2.0	Roberts et al. 1979
Rainbow troat (<i>Decrybrokan mytax</i>) Frih FW 455 Kidney $$ 960 0.47 2051 B Rainbow troat (<i>Decrybrokan mytax</i>) Frih FW 455 Kidney $$ 960 0.47 2051 B Rainbow troat (<i>Decrybrokan mytax</i>) Frih FW 455 Kidney $$ 500 0.47 2051 B 14910.65 Rainbow troat (<i>Decrybrokan mytax</i>) Frih FW 455 Kidney $$ 3900 0.47 2051 B 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14910.65 7 2051 14 7 2050 14 14010.65 15 14 14 15 14 14 15 14 15 <	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Kidney	ł	379	01	37.9	Calamari et al. 1982
Rainbow troat (<i>force/hynolas mylas</i>) Each FW 455 Kidney $=$	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Kidney	I	980	0.47	2085.1	
Rainbow troat (<i>Oncorrhynchus mykis</i>) Fish FW 453 Kidney $$	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	K idney	!	16400	8.1	1.1116	-
Rainbow troat (<i>Oncorrhynchus mytist</i>) Fish FW 560 Kidney 510 53 7236.4 8 Rainbow troat (<i>Oncorrhynchus mytist</i>) Fish FW 90 Kidney 510 10 310 53 7236.4 Rainbow troat (<i>Oncorrhynchus mytist</i>) Fish FW 90 Kidney 500 1300 01 330 2232.4 Rainbow troat (<i>Oncorrhynchus mytist</i>) Fish FW 455 Liver	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Kidney	ł	52600	3.4	15470.6	
Randow tront (<i>Drechynchus mytas</i>) Fish FW 14 Kidney 510 102 9 11.1 R Randow tront (<i>Drechynchus mytas</i>) Fish FW 180 Liver 300 102 9 11.3 R Randow tront (<i>Drechynchus mytas</i>) Fish FW 453 Liver 300 100 343 3617.6 Randow tront (<i>Drechynchus mytas</i>) Fish FW 453 Liver 300 10 34 3617.6 Randow tront (<i>Drechynchus mytas</i>) Fish FW 453 Liver 1100 34 3617.8 Randow tront (<i>Drechynchus mytas</i>) Fish FW 453 Muscle 1100 34 3617.8 Randow tront (<i>Drechynchus mytas</i>) Fish FW 453 Muscle 200 191 31 31 3 31 3 31 3 31 3 31 3 31 3 31	Cadmium	Rainbow trout (Oncorhunchus mykiss)	Fish	FW	560	Kidney	I	39800	5.5	7236.4	
Randow treat (<i>Checolynchus mytas</i>) Fish FW 90 Kidney 750 150 10 1300 130 130 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Liver 130 131 2 301 8 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Liver 1300 0.47 230.43 3 301.45 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Liver 1300 0.47 230.45 3 301.45 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Liver 1200 34 301.45 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Muscle 43 10 0.41 34 301.45 Randow treat (<i>Checolynchus mytas</i>) Fish FW 453 Muscle 1200 041 319 6 6 13 301.45 Randow treat (<i>Checolynchus </i>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	14	Kidney	510	102	6	11.3	Roberts et al. 1979
Rainbow rout (<i>freen-hynechas myldss</i>) Fish FW 180 Live - 300 10 341 C Rainbow rout (<i>freen-hynechas myldss</i>) Fish FW 455 Live - 100 341 314 3175 B Rainbow rout (<i>freen-hynechas myldss</i>) Fish FW 455 Live - 100 341 314 3175 B Rainbow rout (<i>freen-hynechas myldss</i>) Fish FW 455 Live - 1100 54 2018 34 3175 B 3105 B 31223 3 3175 B 310 10 341 310 10 341 310 10 341 3115 B 311 B 34 311 B 311 B 311 B 311 B 311 B 311 B 311 <td< td=""><td>Cadmium</td><td>Rainbow trout (Oncorhynchus mykiss)</td><td>Fish</td><td>FW</td><td>90</td><td>Kidney</td><td>7500</td><td>1500</td><td>01</td><td>150.0</td><td>_</td></td<>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	90	Kidney	7500	1500	01	150.0	_
Rainbow rout (<i>Orechynchus mytus</i>) Fish FW 455 Liver	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Liver	I	380	0	38.0	Calamari et al. 1982
Rainbow troat (<i>Orcet/proclus mytas</i>) Fish FW 455 Liver $=$ 300 18 3222.2 B Rainbow troat (<i>Orcet/proclus mytas</i>) Fish FW 455 Liver $=$ 1100 54 78 2018.2 2018.2 2018.2 <td< td=""><td>Cadmium</td><td>Rainbow trout (Oncorhynchus mykiss)</td><td>Fish</td><td>FW</td><td>455</td><td>Liver</td><td>I</td><td>1100</td><td>0.47</td><td>2340.4</td><td></td></td<>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Liver	I	1100	0.47	2340.4	
Rainbow tron(<i>Decrifynchus mytss</i>)FishFW455Liver-1200343617.6Rainbow tron(<i>Decrifynchus mytss</i>)FishFW560Liver-1200352018.2Rainbow tron(<i>Decrifynchus mytss</i>)FishFW90Liver2601010101343617.6Rainbow tron(<i>Decrifynchus mytss</i>)FishFW180Liver25001001010104.0Rainbow tron(<i>Decrifynchus mytss</i>)FishFW183Muscle-230047314.3234.3Rainbow tron(<i>Decrifynchus mytss</i>)FishFW455Muscle-2601.888.95Rainbow tron(<i>Decrifynchus mytss</i>)FishFW455Muscle-2601.888.95Rainbow tron(<i>Decrifynchus mytss</i>)FishFW455Muscle-2601.888.95Rainbow tron(<i>Decrifynchus mytss</i>)FishFW455Muscle-2601.888.95Rainbow tron(<i>Decrifynchus mytss</i>)FishFW210WB2000.011200.011200.01Rainbow tron(<i>Decrifynchus mytss</i>)FishFW210WB2000.011200.011200.01Rainbow tron(<i>Decrifynchus mytss</i>)FishFW210WB2000.01200.01200.01Rainbow tron	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Liver	ł	5800	1.8	3222.2	-
Rainbow troat (<i>frace/hyrchus myltss</i>) Fish FW 560 Liver 200 53 2018.2 B Rainbow troat (<i>frace/hyrchus myltss</i>) Fish FW 14 Liver 200 53 2018.2 8 8 Rainbow troat (<i>frace/hyrchus myltss</i>) Fish FW 13 FW 13 Liver 200 53 2018.2 8 8 8 8 8 8 8 8 9 53 2018.2 8 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8 9 53 2018.2 8 8	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Liver	I	12300	3.4	3617.6	_
Rainbow troat (<i>Orecrhynchus mytas</i>) Fish FW 14 Liver 260 52 9 58 R Rainbow troat (<i>Orecrhynchus mytas</i>) Fish FW 180 Muscle 230 1040 10 1040 18 58 8 58 8 58 58 8 58 58 10 43 0 10 1040 10 1040 13 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 51 57 51 58 58 58 58 58 51 58 </td <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>560</td> <td>Liver</td> <td>ł</td> <td>00111</td> <td>5.5</td> <td>2018.2</td> <td></td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	560	Liver	ł	00111	5.5	2018.2	
Rainbow total (Oncorhynchus mykts) Fish FW 90 Liver 5200 1040 10 13 C Rainbow total (Oncorhynchus mykts) Fish FW 455 Muscle 43 10 43 C Rainbow total (Oncorhynchus mykts) Fish FW 455 Muscle 10 13 C Rainbow total (Oncorhynchus mykts) Fish FW 455 Muscle 10 14 331.9 E Rainbow total (Oncorhynchus mykts) Fish FW 455 Muscle 60 1.8 83.9 E Rainbow total (Oncorhynchus mykts) Fish FW 210 WB 200 68 10 48 33.9 E Rainbow total (Oncorhynchus mykts) Fish FW 210 WB 200 94 10 13 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 1 30.0 <t< td=""><td>Cadmium</td><td>Rainbow trout (Oncorhynchus mykiss)</td><td>Fish</td><td>FW</td><td>14</td><td>Liver</td><td>260</td><td>52</td><td>6</td><td>5.8</td><td>Roberts et al. 1979</td></t<>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	14	Liver	260	52	6	5.8	Roberts et al. 1979
Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 180 Muscle 43 10 43 C Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 455 Muscle 250 0.47 5119 E Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 455 Muscle 250 0.47 5119 E Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 455 Muscle 60 18 83.9 E Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 240 10 61 13.4 182.4 Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 280 96 10 18.24 5 Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 280 96 1 380 1 380 1 380 1 380 1 380 1 380 1 380 1 380 1 380 1 380 1 1 3	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	90	Liver	5200	1040	01	104.0	
Rainbow trout (Oncorhynechus mykks)FishFW455Muscle-2500.47531.9Rainbow trout (Oncorhynechus mykks)FishFW455Muscle-2500.47531.9Rainbow trout (Oncorhynechus mykks)FishFW455Muscle-6003.4182.4Rainbow trout (Oncorhynechus mykks)FishFW14Spleen0090.01Rainbow trout (Oncorhynechus mykks)FishFW210WB34068106.8FRainbow trout (Oncorhynechus mykks)FishFW210WB280500.11380.06Rainbow trout (Oncorhynechus mykks)FishFW210WB280500.112000.06Rainbow trout (Oncorhynechus mykks)FishFW210WB2809.0222432.5Rainbow trout (Oncorhynechus mykks)FishFW7Bain100681<1	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	ΕW	180	Muscle	1	43	10	4.3	Calamari et al. 1982
Rainbow trout (<i>Oncorhynchus mykus</i>) Fish FW 45 Muscle 160 1.8 88.9 E Rainbow trout (<i>Oncorhynchus mykus</i>) Fish FW 45 Muscle 160 1.8 88.9 E Rainbow trout (<i>Oncorhynchus mykus</i>) Fish FW 14 55 Muscle 620 3.4 182.4 E Rainbow trout (<i>Oncorhynchus mykus</i>) Fish FW 210 WB 280 50 0.1 500.0 6 8 0 6 8 00 6 8 00.0 58 6 10 0 8 0 6 10 6 8 00.0 1 120.0 1 120.0 18 18.0 1 12.0 1 12.0 1 1 12.0 1 <t< td=""><td>Cadmium</td><td>Rainbow trout (Oncorhynchus mykiss)</td><td>Fish</td><td>FW</td><td>455</td><td>Muscle</td><td>1</td><td>250</td><td>0.47</td><td>531.9</td><td>_</td></t<>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Muscle	1	250	0.47	531.9	_
Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 455 Muscle 620 3.4 182.4 E Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 14 Spleen 0 0 9 0.0 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 340 68 10 68 10 68 10 68 10 68 10 68 10 68 10 68 10 68 10 68 10 63 8 10 68 10 23 10 1	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Muscle	1	160	1.8	88.9	
Rainbow trout (Oncorhynchus mykis) Fish FW 14 Spleen 0 0 9 0.0 F Rainbow trout (Oncorhynchus mykis) Fish FW 210 WB 340 68 10 6.8 F Rainbow trout (Oncorhynchus mykis) Fish FW 210 WB 240 120 0.01 12000.0 Rainbow trout (Oncorhynchus mykis) Fish FW 210 WB 1400 1800 1 300 68 10 6.8 60 6 0.0 0.0 0.0 6 0.0 6 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	455	Muscle	I	620	3.4	182.4	
Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 90 Spleen 340 68 10 6.8 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 440 120 0.01 12000.0 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 1400 380 1 300 6.8 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 1400 380 1 300 6.8 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 210 WB 1400 380 1 300 F Rainbow trout (<i>Oncorhynchus mykiss</i>) Fish FW 70 WB 2900 540 4.8 200.0 1 300 1 300 6.8 1 1 200.0 1 1 200.0 1 1 300 6.8 1 0 6.8 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>14</td> <td>Spleen</td> <td>0</td> <td>0</td> <td>6</td> <td>0.0</td> <td>Roberts et al. 1979</td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	14	Spleen	0	0	6	0.0	Roberts et al. 1979
Rainbow trout (<i>Oncorhynchus mykis</i>)FishFW210WB4401200.0112000.0Rainbow trout (<i>Oncorhynchus mykis</i>)FishFW210WB280500.1500.01Rainbow trout (<i>Oncorhynchus mykis</i>)FishFW210WB280500.1500.01Rainbow trout (<i>Oncorhynchus mykis</i>)FishFW210WB2805402.2245.51Rainbow trout (<i>Oncorhynchus mykiss</i>)FishFW70WB28005402.2245.51Rainbow trout (<i>Oncorhynchus mykiss</i>)FishFW70WB2809604.8200.01325.5Rainbow trout (<i>Oncorhynchus mykiss</i>)FishFW70WB2809604.8200.01325.51Rainbow trout (<i>Oncorhynchus mykiss</i>)FishFW70WB2809604.8200.017Stickleback (species not provided)FishFW7Brain11802361202.07.07.0Stickleback (species not provided)FishFW7Gall bladder325010700.17.07.07.0Stickleback (species not provided)FishFW7Gall bladder325010700.17.07.07.0Stickleback (species not provided)FishFW7Gall bladder321010701.07.07.07.0 <td>Cadmium</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>8</td> <td>Spleen</td> <td>340</td> <td>68</td> <td>0</td> <td>6.8</td> <td>Roberts et al. 1979</td>	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	8	Spleen	340	68	0	6.8	Roberts et al. 1979
Rainbow trout (<i>Drearlynchus mykis</i>) Fish FW 210 WB 280 50 0.1 500.0 Rainbow trout (<i>Drearlynchus mykis</i>) Fish FW 210 WB 1400 380 1 380.0 Rainbow trout (<i>Drearlynchus mykis</i>) Fish FW 210 WB 1400 380 1 380.0 Rainbow trout (<i>Oncorhynchus mykis</i>) Fish FW 210 WB 2 0.1 500.0 4.8 200.0 4 32.5 1 380.0 6 4.8 200.0 4 32.5 1 380.0 6 4.8 200.0 4 32.5 1 380.0 6 4.8 200.0 4 32.5 1 32.5 1 32.5 1 32.5 1 1 380.0 6 4.8 32.5 1 1 32.5 1 1 32.5 1 1 32.5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 <td< td=""><td>Cadmium</td><td>Rainbow trout (Oncorhynchus nykiss)</td><td>Fish</td><td>FW</td><td>210</td><td>WB</td><td>440</td><td>120</td><td>0.01</td><td>12000.</td><td></td></td<>	Cadmium	Rainbow trout (Oncorhynchus nykiss)	Fish	FW	210	WB	440	120	0.01	12000.	
Rainbow trout (Oncor/tynchus mykiss)FishFW210WB1400380138001Rainbow trout (Oncor/tynchus mykiss)FishFW210WB19005402.2245.51Rainbow trout (Oncor/tynchus mykiss)FishFW70WB28009604.8200.01Rainbow trout (Oncor/tynchus mykiss)FishFW70WB28009604.8200.01Stickleback (species not provided)FishFW7Brain11802361202.07.0Stickleback (species not provided)FishFW7Brain61012210700.17.0Stickleback (species not provided)FishFW7Gall bladder42208441207.07.0Stickleback (species not provided)FishFW7Gall bladder525010700.17.07.0Stickleback (species not provided)FishFW7Gall bladder525010700.17.07.0Stickleback (species not provided)FishFW7Gall bladder525010702.07.07.0Stickleback (species not provided)FishFW7Gall bladder525010702.07.07.0Stickleback (species not provided)FishFW7Gall bladder25105007.07.07.0Stickleback (species not provided)Fish	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	210	WB	280	50	0.1	500.0	_
Rainbow trout (<i>Oncorhynchus mytiss</i>)FishFW210WB19005402.2245.51Rainbow trout (<i>Oncorhynchus mytiss</i>)FishFW70WB28009604.8200.01Rainbow trout (<i>Oncorhynchus mytiss</i>)FishFW70WB130432.51Stickleback (species not provided)FishFW7Brain11802361202.07.0Stickleback (species not provided)FishFW7Brain61012210700.17.0Stickleback (species not provided)FishFW7Gall bladder42208441207.07.0Stickleback (species not provided)FishFW7Gall bladder525010700.17.07.0Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gand2310280610701.07.07.0Stickleback (species not provided)FishFW7Gand25102007.07.07.0Stickleback (species not provided)FishFW7Gand25102001.02.67.0Stickleback (species not provided)Fish	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	210	WB	1400	380		380.0	_
Rainbow trout (Oncorthuncturs mytiss)FishFW210WB28009604.8200.01Rainbow trout (Oncorthuncturs mytiss)FishFW70WB130432.51Stickleback (species not provided)FishFW7Brain11802361202.07.0Stickleback (species not provided)FishFW7Brain61012210700.17.0Stickleback (species not provided)FishFW7Gall bladder42208441207.07.0Stickleback (species not provided)FishFW7Gall bladder5250105010700.10.1Stickleback (species not provided)FishFW7Gall bladder525010700.10.10.1Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gand2310280610702.67.07.0Stickleback (species not provided)FishFW7Gand25102007.07.07.0Stickleback (species not provided)FishFW7Gand25102001.02.67.0Stickleback (species not provided)Fish<	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	210	WB	0061	540	2.2	245.5	_
Rainbow trout (<i>Oncorhynchus mytiss</i>)FishFW70WB130432.57Stickleback (species not provided)FishFW7Brain11802361202.07Stickleback (species not provided)FishFW7Brain61012210700.17Stickleback (species not provided)FishFW7Gall bladder42208441207.07.0Stickleback (species not provided)FishFW7Gall bladder5250105010701.07.0Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gall bladder525010701.07.07.0Stickleback (species not provided)FishFW7Gand2310280610702.67.0Stickleback (species not provided)FishFW7Gonad25105021202.67.0Stickleback (species not provided)FishFW7Gonad251050210700.26.17.0Stickleback (species not provided)FishFW7Gonad251050210702.67.0Stickleback (species not provided)FishFW7Gonad251050210702.67.0Stickleback (species not provided)FishF	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	210	WB	2800	960	4.8	200.0	_
Stickleback (species not provided)FishFW7Brain11802361202.0Stickleback (species not provided)FishFW7Brain61012210700.1Stickleback (species not provided)FishFW7Gall bladder42208441207.0Stickleback (species not provided)FishFW7Gall bladder42208441207.07.0Stickleback (species not provided)FishFW7Gill45909181207.7Stickleback (species not provided)FishFW7Gill14030280610701.0Stickleback (species not provided)FishFW7Gonad2510204.2Stickleback (species not provided)FishFW7Gonad2510201.02.6Stickleback (species not provided)FishFW7Gonad2510204.27.7Stickleback (species not provided)FishFW7Gonad25102010702.6Stickleback (species not provided)FishFW7Gonad2510807010700.2Stickleback (species not provided)FishFW7Gonad2510807010700.2Stickleback (species not provided)FishFW7Gunad19780395610700.2Stickleback (species not provided)FishFW7	Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	20	WB	1	130	4	32.5	
Stickleback (species not provided) Fish FW 7 Brain 610 122 1070 0.1 Stickleback (species not provided) Fish FW 7 Gall bladder 4220 844 120 7.0 7 Stickleback (species not provided) Fish FW 7 Gall bladder 4220 844 120 7.0 7 Stickleback (species not provided) Fish FW 7 Gill 4590 918 120 7.7 7 Stickleback (species not provided) Fish FW 7 Gill 44930 2806 1070 2.6 7.7 7 Stickleback (species not provided) Fish FW 7 Gonad 2510 200 1.0 2.6 7.7 7 Stickleback (species not provided) Fish FW 7 Gonad 2510 302 1070 0.2 6 7.7 7 7 7 7 7 7 7 7 7 <t< td=""><td>Cadmium</td><td>Stickleback (species not provided)</td><td>Fish</td><td>FW</td><td>7</td><td>Brain</td><td>1180</td><td>236</td><td>120</td><td>2.0</td><td>Woodworth and Pascoe 1983</td></t<>	Cadmium	Stickleback (species not provided)	Fish	FW	7	Brain	1180	236	120	2.0	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gall bladder 42.0 84.4 12.0 7.0 Stickleback (species not provided) Fish FW 7 Gall bladder 5250 1050 1070 1.0 7 Stickleback (species not provided) Fish FW 7 Gill 4590 918 120 7.7 7 Stickleback (species not provided) Fish FW 7 Gill 14030 2806 1070 1.0 7.7 Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 7.7 7 Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 2.6 7.2 Stickleback (species not provided) Fish FW 7 Gonad 1100 220 1070 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2	Cadmium	Stickleback (species not provided)	Fish	FW	7	Brain	610	122	1070	0.1	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gall bladder 5250 1050 1070 1.0 Stickleback (species not provided) Fish FW 7 Gill 4590 918 120 7.7 7 Stickleback (species not provided) Fish FW 7 Gill 14030 2806 1070 2.6 7.7 7 <td< td=""><td>Cadmium</td><td>Stickleback (species not provided)</td><td>Fish</td><td>FΨ</td><td>7</td><td>Gall bladder</td><td>4220</td><td>844</td><td>120</td><td>7.0</td><td>Woodworth and Pascoe 1983</td></td<>	Cadmium	Stickleback (species not provided)	Fish	FΨ	7	Gall bladder	4220	844	120	7.0	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gill 4590 918 120 7.7 Stickleback (species not provided) Fish FW 7 Gill 14030 2806 1070 2.6 7.7 Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 4.2 7.6 Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 4.2 7 Stickleback (species not provided) Fish FW 7 Guad 1100 220 1070 0.2 7 Stickleback (species not provided) Fish FW 7 Gut 8970 1794 120 15.0 Stickleback (species not provided) Fish FW 7 Gut 19780 3956 1070 3.7	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gall bladder	5250	1050	1070	1.0	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gill 14030 2806 1070 2.6 7 Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 4.2 7 Stickleback (species not provided) Fish FW 7 Gonad 1100 220 1070 0.2 7 7 Stickleback (species not provided) Fish FW 7 Gunad 1100 220 1070 0.2 7 7 31 7 7 31 7 7 31 7 7 37 7 7 7 1 1 1 1 1 0 2 1 7 1	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gill	4590	918	120	7.7	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gonad 2510 502 120 4.2 Stickleback (species not provided) Fish FW 7 Gonad 1100 220 1070 0.2 Stickleback (species not provided) Fish FW 7 Gut 8970 1794 120 15.0 Stickleback (species not provided) Fish FW 7 Gut 19780 3956 1070 3.7	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gill	14030	2806	1070	2.6	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gonad 1100 220 1070 0.2 Stickleback (species not provided) Fish FW 7 Gut 8970 1794 120 15.0 Stickleback (species not provided) Fish FW 7 Gut 8970 1794 120 15.0	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gonad	2510	502	120	4.2	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gut 8970 1794 120 15.0 1 Stickleback (species not provided) Fish FW 7 Gut 19780 3956 1070 3.7	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gonad	0011	220	1070	0.2	Woodworth and Pascoe 1983
Stickleback (species not provided) Fish FW 7 Gut 19780 3956 1070 3.7	Cadmium	Stickleback (species not provided)	Fish	FW	7	Gut	8970	1794	120	15.0	-
	Cadmium	Stickleback (species not provided)	Fish	FΨ	7	Gut	19780	3956	1070	3.7	Woodworth and Pascoe 1983

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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November 5, 1999

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Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(J/8rl)	BCF	Reference
Cadmium	Stickleback (species not provided)	Fish	ΕW	7	Kidnev	4820	964	120	0 8	Woodworth and Pascos 1083
Cadmium	Stickleback (species not provided)	Fish	FW	1	Kidnev	3170	634	1070	0.6	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Liver	9030	1806	120	15.1	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Liver	25680	5136	1070	4.8	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Muscle	2280	456	120	3.8	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Muscle	930	186	1070	0.2	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Skin	3280	656	120	5.5	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Skin	5460	1092	1070	1.0	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Spleen	3420	684	120	5.7	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	Spleen	4940	988	1070	0.9	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	WB	300	99	120	0.5	Woodworth and Pascoe 1983
Cadmium	Stickleback (species not provided)	Fish	FW	7	WB	750	150	1070	0.1	Woodworth and Pascoe 1983
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	10	WB	3050	610	0.25	2440.0	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	10	WB	1700	340	0.05	6800.0	
Cadmium	Amphipod (Ilyalella azteca)	Invert	FW	01	WB	1400	280	0.01	28000.0	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	10	WB	3600	720	0.25	2880.0	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	10	WB	1900	380	0.05	7600.0	•••
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	10	WB	1500	300	0.01	30000.0	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	42	WB	23000	4600	<0.18	25555.6	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	42	WB	32000	6400	2.28	2807.0	_
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	42	WB	23000	4600	8.98	512.2	
Cadmium	Amphipod (Hyalella azteca)	Invert	FW	42	WB	42000	8400	0.38	22105.3	_
Cadmium	Asiatic clam (Corbicula Juminea)	Invert	FW	28	Soft parts	75450	7545	23	328.0	-
Cadmium	Asiatic clam (Corbicula fluminea)	Invert	FW	28	Soft parts	95450	9545	55	173.5	
Cadmium	Bay scallop (Argopecten irradians)	Invert	SW	42	Soft parts	1225000	122500	70	1750.0	
Cadmium	Bay scallop (Argopecten irradians)	Invert	SW	42	Soft parts	1745000	174500	130	1342.3	_
Cadmium	Beetle (Dytiscidae)	Invert	FW		WB	!	I	I	164	USEPA 1985b
Cadmium	Beetle (Dytiscidae)	Invert	FW		WB	ł	I	I	260	USEPA 1985b
Cadmium	Biting midge (Ceratopogonidae)	Invert	FW		WB	I	ļ	ł	936	USEPA 1985b
Cadmium	Biting midge (Ceratopogonidae)	Invert	FW		WB	I	I	1	662	USEPA 1985b
Cadmium	Blue mussel (Mytilus edulis)	Invert	ΜS		Soft parts	I	I	I	113	USEPA 1985b
Cadmium	Blue mussel (Myrilus edulis)	Invert	ΜS	35	Soft parts	40519	5470	01	547.0	Phillips 1976
Cadmium	Blue mussel (Mytilus edulis)	Invert	ΜS	35	Soft parts	50519	6820	20	341.0	
Cadmium	Blue mussel (Mytilus edulis)	Invert	ΜS	35	Soft parts	44593	6020	20	301.0	
Cadmium	Blue mussel (Mytilus edulis)	Invert	SW	35	Soft parts	49481	6680	40	167.0	-
Cadmium	Caddisfly (Hydropsyche betteni)	Invert	FW	28	WB	10000	20000	•	6666.7	•••
Cadmium	Caddisfly (Hydropsyche betteni)	Invert	FW	28	WB	20000	40000	8.3	4819.3	
Cadmium	Caddisfly (Hydropsyche betteni)	Invert	FW	28	ШB	250000	5000	27.5	1818.2	
Cadmium	Caddisfly (Hydropsyche betteni)	Invert	FW	28	WB	30000	00009	85.5	701.8	Spehar et al.

Critical Review of the Use of Bivaccumulation Potential for Hazard Classification of Metals and Metal Compounds

AR 044661

November 5, 1999

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		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(ng/L)	BCF	Reference
Cadmium	Cladoceran Waphnia magna)	Invert	FW	4	WB	400	80	0.22	363.6	Poldoski 1979
Cadmium	Cladoceran (Daphnia magna)	Invert	FW	4	WB	0001	200	10.1	198.0	Poldoski 1979
Cadmium	Cladoceran (Daphnia magna)	Invert	FW	4	WB	2100	420	3.37	124.6	Poldoski 1979
Cadmium	Cladoceran (Daphnia magna)	Invert	FW	4	WB	4000	800	10.12	1.9.1	Poldoski 1979
Cadmium	Cladoc era n (Daphnia magna)	Invert	FW	7	WB	48400	9680	20	484.0	Winner 1984
Cadmium	Cladoceran (Daphnia magna)	Invert	FW	7	WB	43300	8660	20	433.0	Winner 1984
Cadmium	Crayfish (Cambarus latimanus)	Invert	FW	150	WB	21960	7394	01	739.4	Thorp et al. 1979
Cadmium	Crayfish (Orconectes propinguus)	Invert	FW	80	WB	25000	5000	10	500.0	Gillespie et al. 1977
Cadmium	Crayfish (Orconectes propinguus)	Invert	FW	80	WB	140000	28000	001	280.0	Gillespie et al. 1977
Cadmium	Crayfish (Orconectes propinguus)	Invert	FW	œ	WB	540000	108000	0001	108.0	Gillespie et al. 1977
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	Abdominal muscle	3900	780	400	2.0	Mirenda 1986b
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	Antennal Gland	39900	7980	400	20.0	Mirenda 1986b
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	Carapace	4900	086	400	2.5	Mirenda 1986b
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	Cill	225300	45060	400	112.7	Mirenda 1986b
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	Hepatopancreas	90700	18140	400	45.4	Mirenda 1986b
Cadmium	Crayfish (Oronectes virilis)	Invert	FW	14	WB	28400	5680	400	14.2	Mirenda 1986b
Cadmium	Damselfly Uschnura sp.)	Invert	FW		WB	I	I	I	1,300	USEPA 1985b
Cadmium	Damselfly Uschnura sp.)	Invert	FW		WB	I	1	ł	928	USEPA 1985b
Cadmium	Dragonfly (Pantala hymenea)	Invert	FW		WB	I	I	ł	736	USEPA 1985b
Cadmium	Dragonfly Prantala hymenea)	Invert	FW		WB	ł	1	I	680	USEPA 1985b
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	SW		Soft parts	I	I	I	2,150	USEPA 1985b
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	SW		Soft parts	1	I	I	1,830	USEPA 1985b
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΝS	119	Soft parts	I	106700	100	1067.0	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΝS	112	Soft parts	I	105700	001	1057.0	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΝS	16	Soft parts	ł	96500	200	482.5	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΝS	16	Soft parts	ł	125800	200	629.0	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	SW	119	Soft parts	Ι	106700	100	1067.0	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΜS	112	Soft parts	I	105700	001	1057.0	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	ΝS	91	Soft parts	1	96500	200	482.5	Shuster and Pringle 1969
Cadmium	Eastern oyster (Crassostrea virginica)	Invert	SW	16	Soft parts	۱	125800	200	629.0	Shuster and Pringle 1969
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	ΜS	42	WB	13400	2680	0.08	33500.0	Pesch and Stewart 1980
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	SW	42	WB	20700	4140	0.14	29571.4	Pesch and Stewart 1980
Cadmium	Grass shrimp (Palaemonetes vulgaris)	Invert	SW	28	WB	ł	20000	7.9	2531.6	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes vulgaris)	Invert	ΜS	28	WB	1	3200	12.7	252.0	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes vulgaris)	Invert	SW	28	WB	ł	5000	28.2	177.3	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes vulgaris)	Invert	ΜS	28	WB	I	0009	35.9	167.1	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	ΝS	35	WB	I	8000	54	148.1	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	SW	35	WB	I	13000	83	156.6	Nimmo et al. 1977
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	ΜS	21	WB	35000	7000	50	140.0	Vernberg et al. 1977
Cadmium	Grass shrimp (Palaemonetes pugio)	Invert	SW	21	WB	20000	4000	50	80.0	Vernberg et al. 1977

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(hg/L)	BCF	Reference
Cadmium	Mayfly (Ephemeroptera)	Invert	FW		WR	1	I		063.1	IICEDA 1006L
Cadmium	Mayfly (Ephemeroptera)	Invert	ΕW		aw BW	1			003 6	USELA 19030 Lifeda 10044
Cadmium	Midge (Chironomidae)	Invert	FW		aw				00C C	U3EFA 1903U
Cadmium	Midge (Chironomidae)	Invert	ΕM		a M				10212	U3EFA 19030 LISEDA 1005L
Cadmium	Midge (Chironomus riparius)	Invert	ΕN	30	a.v	'	110000	1 2	0.00311	- •
Cadmium	Midge (Chironomus riparius)	Invert) generation:	am		0000	8	0.00011	-
Cadmium	Midee (Chironomus rinarius)	Innet		NUMBERING		00071	0047		1.203.2	Postma and Davids 1995
Cadmium	Midae (Chiranamus rinarius)			-00-97	a w	00005	0000	5.6	1071.4	Postma and Davids 1995
Cadmium	Mussel (Flintic complete)		Ň	с •	AB 2 0 2	724800	44960	83.4	539.1	Postma et al. 1996
	Mussel Kritpito complanaia	Invert	ΕW	r.	Soft tissue	21000	2100	120	17.5	Wang and Evans 1993
Cadmium	Mussel (Eiliptio complanata)	Invert	FW	ŕ	Soft tissue	16000	1600	120	13.3	Wang and Evans 1993
Cadmium	Mussel (Elliptio complanata)	Invert	FW	••	Soft tissue	9500	950	120	7.9	Wane and Evans 1993
Cadmium	Mussel (Elliptio complanata)	Invert	FW	Ē	Soft tissue	8000	800	120	67	Wane and Evant 1003
Cadmium	Mussel (Elliptio complanata)	Invert	FW	5	Soft tissue	6000	009		0.2	Wang and Evens 1003
Cadmium	Mussel (Myrilus edulis)	Invert	SW	17	Soft tissue	10000	1000	4	0011	Doutean at al 1000
Cadmium	Mussel (Mytilus edulis)	Invert	SW	17	Soft tissue	15000	15000	801	127.6	Poulsen et al 1097
Cadmium	Oyster (Crassostrea virginica)	Invert	MS	280	Soft tissue	010901	00001	<u>}</u>		Toursen et al. 1902
Cadmium	Oyster (Crassostrea virginica)	Invert	MS	252	Soft tiseue	00000			0.41/2	Latuogian and Uncer 19/0
Cadmium	Ovster (Craccostrea virginica)		1110			00020	0069	n ;	1/80.0	Zaroogian 1980
Cadmium	Ovster (Crastastrea virginica)		10.0	272		0000/1	1/600	2 :	1760.0	Zaroogian 1980
Cedminn	Outer (Construction Structure)			767	Soli lissue	000767	00767	51	1946.7	Zaroogian 1980
	Opsici (crassosirea virginica)	Invert	SW	259	Soft tissue	00016	0016	s	1820.0	Zaroogian and Morrison [98]
Cadmium	Uyster (Crassostrea virginica)	Invert	SW	259	Soft tissue	270000	27000	15	1800.0	Zaroogian and Morrison 1981
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	SW	30	Muscle	ł	3800	62	48.1	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΜS	30	Muscle	I	10400	182	57.1	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΝS	30	Muscle	I	17000	307	55.4	Nimmo et al. 1977
Cadmium	Pink shrimp (<i>Penaeus duorarum</i>)	Invert	ΜS	30	Muscle	1	19400	586	33.1	Nimmo et al. 1977
Cadmium	Pink shrimp (<i>Penaeus duorarum</i>)	Invert	SW	30	Muscle	1	30100	866	34.8	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΝS	30	Muscle	I	30500	1285	23.7	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΜS	14	Gill	I	51600	224	230.4	Nimmo et al 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	SW	14	Gill	ł	60300	515	117.1	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΜS	14	Gill	1	149800	736	203.5	Nimmo et al. 1977
Cadmium	Pink shrimp (Penaeus duorarum)	Invert	ΜS	14	Gill	Ι	176500	1010	174.8	Nimmo et al 1977
Cadmium	Polychaete (Ophryotrocha diadema)	Invert	ΜS	2	WB	1708000	341600	1000	341.6	Klockner 1979
Cadmium	Polychaete (Ophryotrocha diadema)	Invert	ΜS	29	WB	315000	63000	001	630.0	Klockner 1970
Cadmium	Polychaete (Ophryotrocha diadema)	Invert	ΜS	49	WB	7900	1580	2	158.0	Klockner 1070
Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	œ	Gill	. 760	152	2	76.0	Zelikoff et al 1005
Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	17	Gill	850	170		85.0	Zelikuff et al. 1005
Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	30	Gill	\$50	011		55.0	Zelikoff et al. 1005
Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	17	Liver	750	\$	• •	0.50	Zelikali et al. 1995
Cadmium	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	30	Liver	1000	2009	• ~	1000	Zalikoff at al. 1993
						****		1	2.000	CCHRUN CI MI. 1773

AR 044663

November 5, 1999

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(hg/L)	BCF	Reference
Cadmium	Snail (Physa inteera)	Invert	ΕW	38	a M	COOOS		0	0 7001	
Cadmium	Snail (Physa integra)	Invert		82		150000	20000	• °	0.4021	Special et al. 1976
Cadmium	Soft-shell clam (Mya arenaria)	Invert	ms	93 F	Soft marte		0000	9 S	140.0	openar et al. 1976 Britolo et al. 1976
Cadmium	Soft-shell clam (Mya arenaria)	Invert	SW	202	Soft parts		0006	3 8	0.00	Fringle et al. 1700 Pringle et al. 1968
Cadmium	Stonelly (Pteronarcys dorsata)	Invert	FW	28	WB	7000	1400	-	466.7	Streftst et al. 1078
Cadmium	Stonefly (Pteronarcys dorsata)	Invert	ΕW	28	WB	25000	5000	8.3	602.4	Spehar et al. 1978
Cadmium	Stonefly (Pteronarcys dorsata)	Invert	FW	28	WB	5000	1000	27.5	36.4	Spechar et al 1978
Cadmium	Stonefly (Pteronarcys dorsata)	Invert	FW	28	WB	70000	14000	85.5	163.7	Spehar et al 1078
Cadmium	Stonefly (Pteronarcys dorsata)	Invert	FW	28	WB	100000	20000	238	84.0	Spechar et al. 1978
Cadmium	Sydney Rock Oyster (Saccostrea commercialis)	Invert	ΝS	112	WB	1	I	9.8	12561	Ward 1982
Cadmium	Zebra mussel (Dreissena polymorpha)	Invert	FW	11	Soft parts	2100	210	0.2	1050.0	Kraak et al. 1992
Cadmium	Zebra mussel (Dreissena polymorpha)	Invert	FW	11	Soft parts	0011	110	0.2	550.0	Kraak et al. 1992
Cadmium	Zebra mussel (Dreissena polymorpha)	Invert	FW	11	Soft parts	70000	7000	6	777.8	Kraak et al 1992
Cadmium	Zebra mussel (Dreissena polymorpha)	Invert	FW	77	Soft parts	30000	30000	42	714.3	Knak et al 1992
Cadmium	Zebra mussel (Dreissena polymorpha)	Invert	FW	11	Soft parts	60000	6000	10	5769	Krask et al 1007
Cadmium	Aquatic moss (Rhynchostegium riparioides)	Plant	FW	27	WB	530000	53000	43.6	1215.6	Mersch et al. 1993
Cadmium	Duck weed (Lemna valdiviana)	Plant	FW	21	WB	1	ł		609	LISEPA 1985h
Cadmium	Fem (Salvinia natans)	Plant	FW	21	WB	I	ł	ł	096	11SEPA 1985b
Chromium (III)	Blue mussel (Mytilus edulis)	Invert	SW	42	Soft narts	430000	43000	1000	0.54	McDowell Camero and Camer 1077
Chromium (III)	Soft-shell clam (Mya arenaria)	Invert	SW	42	Soft parts	765000	00592	1000	2.65	McDowell-Carriero and Carner 1077
Chromium (III)	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	I	6280	205 205	125.6	Shuster and Prinole 1969
Chromium (III)	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	1	5810	50	116.2	Shuster and Prinole 1969
Chromium (III)	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	I	11490	100	114.9	Shuster and Pringle 1969
Chromium (III)	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	1	10870	100	108.7	Shuster and Pringle 1969
Chromium (total)	Algae Usterionella japonica)	Algae	SW	25	Cells	5500	550	12	45.8	Riley and Roth 1971
Chromium (total)	Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	4400	440	12	36.7	Riley and Roth 1971
Chromium (total)	Algae (Dunaliella primolecta)	Algae	SW	25	Cells	8400	840	12	70.0	Riley and Roth 1971
Chromium (total)	Algae (Dunaliella tertiolecta)	Algac	SW	25	Cells	3600	360	12	30.0	Riley and Roth 1971
Chromium (total)	Algae (Hemiselmis brunescens)	Algae	ΜS	25	Cells	30000	3000	12	250.0	Riley and Roth 1971
Chromium (total)	Algae (Hemiselmis virescens)	Algae	ΝS	25	Cells	4800	480	12	40.0	Riley and Roth 1971
Chromium (total)	Algae (Micromonas squamata)	Algae	SW	25	Cells	13500	1350	12	112.5	Riley and Roth 1971
Chromium (total)	Algae (Monochrysis lutheri)	Algae	SW	25	Cells	9400	940	12	78.3	Riley and Roth 1971
Chromium (tota!)	Algae (Olisthodiscus luteus)	Algae	SW	25	Cells	14700	1470	12	122.5	Riley and Roth 1971
Chromium (total)	Algae (Phaeodactylum tricornutum)	Algae	ΝS	25	Cells	4400	440	12	36.7	Riley and Roth 1971
Chromium (total)	Algae (Pseudopedinella pyriformis)	Algae	SW	25	Cells	8200	820	12	68.3	Riley and Roth 1971
Chromium (total)	Algae (Stichococcus bacillaris)	Algae	SW	25	Cells	2800	280	12	23.3	Riley and Roth 1971
Chromium (total)	Algae (Tetraseimis tetrathele)	Algae	SW	25	Cells	8000	800	12	66.7	Riley and Roth 1971
Chromium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Kidney	I	3481	200	17.4	Calamari et al. 1982
Chromium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Liver	I	0861	200	9.9	Calamari et al. 1982
Chromium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	22	Muscle		340	2500	0.1	Buhler et al. 1977

Critical Review of the Use of Bioaccumulation Potential for Ilazard Classification of Metals and Metal Compounds

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Metalloid Species ium (Y1) Rainbow trout (Oncorhymchus mykiss) ium (Y1) Rainbow trout (Oncorhymchus mykiss) ium (Y1) Rainbow trout (Oncorhymchus mykiss) ium (Y1) Amphipod (Mlorchestes compressa) ium (Y1) Blue mussel (Myitlus edults) ium (Y1) Eastern oyster (Crassotre a viginica) <			Organism				Amoot I	Discil			
$ \begin{array}{ccccccc} \operatorname{rent}(Y) & Ratrikev treat (Phochynchicat prista) \\ \operatorname{Ratrikev treat (Phochynchicat prista) \\ \operatorname{Ratrike treat (Phochynchicat prista) \\ \operatorname{Ratrikev treat (Phochynchicat prista$	Metal/Metalloid	Species	Type	Type	(days)	Tissue	(Jug/kg-dry)	(µg/kg-wet)	(hg/L)	BCF	Reference
			i		:						
$ \begin{array}{cccccc} (10) \\ (10$		Nalibuw uput (Uncornynchus mykuss)	Fish	×	180	Muscle	I	583	200	2.9	Calamari et al. 1982
	Chromium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	24	WB	13	2.6	10	0.3	Fromm and Stokes 1962
(1) Applied (<i>Mochenes compressis</i>) Inert SW 2500 S00 <	Chromium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	24	WB	1.6	0.32	1.3	0.2	Fromm and Stokes 1962
N(1)Numbined (directore conversal) into (1)InterSV 230 230 64 813 into (1)Ampliped (directore conversal) into (1)InterSV 28 WB 3000 500 <	Chromium (VI)	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	25000	5000	62	80.6	Ahsamilla and Williams 1991
Int (1)Amplified (Affice-formerant)InvertSW28WB3000600103650int (1)Amplified (Affice-formerant)InvertSW28WB3000600103650int (1)Amplified (Affice-formerant)InvertSW28WB3000600103650int (1)Brentward (Mpfifike adult)InvertSW28SN80818125int (1)Brentward (Mpfifike adult)InvertSWSNSN80818125int (1)Brentward (Mpfifike adult)InvertSWSNSNSN800810137232int (1)Brentward (Mpfifike adult)InvertSWSN	Chromium (VI)	Amphipod (Allorchestes compressa)	Invert	ΜS	28	WB	26000	5200	2	813	Aheanulla and Williams 1001
	Chromium (VI)	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	34000	6800	501	0 99	Absanilla and Williams 1001
min (1) Amplipod (<i>Altrochects compress</i>) Inset SW With COMD SW COMD SW	Chromium (VI)	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	12000	6400		515	Ab-months with the structure in the
ture (1) Amplified (Alterchets conjecta) ture SW SA part $=$ </td <td>Chromium (VI)</td> <td>Amphipod (Allorchestes compressa)</td> <td>Invert</td> <td>MS</td> <td>28</td> <td>MB</td> <td>47000</td> <td>0400</td> <td>356</td> <td>14.0</td> <td>Absorbling and Williams 1991</td>	Chromium (VI)	Amphipod (Allorchestes compressa)	Invert	MS	28	MB	47000	0400	356	14.0	Absorbling and Williams 1991
unit (1)Bits muses (syr) (chardis)MostSyr	Chromium (VI)	Amphipod (Allarchestes commessa)	Invert	n s	2		16001				
Image (V)Electronic structureNumber of the structure <t< td=""><td>Chromium (VI)</td><td>Blue mussel (Mviilus edulis)</td><td>Invert</td><td>an s</td><td>07</td><td></td><td>00000</td><td>0006</td><td>747</td><td>905</td><td>Ansanulla and Williams 1991</td></t<>	Chromium (VI)	Blue mussel (Mviilus edulis)	Invert	an s	07		00000	0006	747	905	Ansanulla and Williams 1991
Interval Description Description <thdescription< th=""> <thdescription< th=""> <</thdescription<></thdescription<>	Chromium (VI)	Factorn overlor (Craccostrian virainica)					I	I	ł	761	USETA 1965C
Implying the drammove threadynamics are acconstructured Invert SV SW LSO10005 HS HS LSO1005				A I		SOIT parts	I	I	ł	125	USEPA 1985c
Fehrad minnow <i>Pinngolatis prometa</i>) Fish FW 30 WB 9300 1860 147 127 Fahrad minnow <i>Pinngolatis prometa</i>) Fish FW 30 WB 14300 2860 29.5 9 Fahrad minnow <i>Pinngolatis prometa</i>) Fish FW 30 WB 1300 1600 147 173 Ages (<i>Altarydata spinic</i>) Ages SW 25 Cells 2000 1500 34 308 Ages (<i>Altarydata stillar</i>) Ages SW 25 Cells 2000 150 34 303 Ages (<i>Altarydata stillar</i>) Ages SW 25 Cells 2000 200 34 313 Age (<i>Altarydata stillar</i>) Age SW 25 Cells 2000 200 34 323 Age (<i>Altarydata</i>) Age SW 25 Cells 3000 34 323 Age (<i>Altardata</i>) Age SW 25 Cells 3000 34 323 <td>Chromium (VI)</td> <td>Polychaete (Neanthes arenaceodentata)</td> <td>Invert</td> <td>SW</td> <td>163.3</td> <td>WB</td> <td>22201.005</td> <td>4418</td> <td>16.6</td> <td>266.1</td> <td>Oshida and Word 1982</td>	Chromium (VI)	Polychaete (Neanthes arenaceodentata)	Invert	SW	163.3	WB	22201.005	4418	16.6	266.1	Oshida and Word 1982
Ethend mimow <i>francplates prometas</i>) Fish FW 30 WB 14300 2860 29.5 97 Fathend mimow <i>francplates prometas</i>) Fish FW 30 WB 14300 2860 29.5 97 Relect Attrionelli suponics Ages SW 25 Cells 10000 1000 34 135 Ages (Attrionelli suponics) Ages SW 25 Cells 2000 200 34 135 Ages (Attrionelli suponics) Ages SW 25 Cells 2000 200 34 135 Ages (Merconsuit) Ages SW 25 Cells 2000 200 34 125 Ages (Merconsuit) Ages SW 25 Cells 2000 200 34 273.5 Ages (Merconsuit) Ages SW 25 Cells 2000 200 34 273.5 Ages (Merconsuit) Ages SW 25 Cells 2000 200	Cobalt	Fathcad minnow (Pimephales promelas)	Fish	FW	30	WB	9300	1860	14.7	127	Lind et al. Manuscript
Fathed minows (<i>prime for pronelar</i>)FishFW30WB2130043787Lind et al. MinusAgree Charavedia (<i>prime res</i>)Agree SW25Cells2000010500343133Riby and Reh IAgree Charavedia (<i>primereas</i> s)Agree SW25Cells2000010500341333Riby and Reh IAgree Charavedia (<i>primereas</i>)Agree SW25Cells200002500341333Riby and Reh IAgree Charavedia (<i>primereas</i>)Agree SW25Cells270002500341333Riby and Reh IAgree Charavedia (<i>primereas</i>)Agree SW25Cells270002500341333Riby and Reh IAgree CharavediaAgree SW25Cells270002000342333Riby and Reh IAgree CharavediaAgree SW25Cells270002100342333Riby and Reh IAgree Microsonic systematoAgree SW25Cells270002100342333Riby and Reh IAgree Microsonic systematoAgree SW25Cells210000210002100342333Riby and Reh IAgree Microsonic systematoAgree SW25Cells2100002100021002133Riby and Reh IAgree Microsonic systematoAgree SW25Cells2100002100021002133Riby and Reh IAgree Microsonic systematoAgree SW25Cells	Cobalt	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	14300	2860	29.5	76	Lind et al Manuscrint
Ages (Attentional is synonica) Ages SW 25 Cells 10000 1000	Cobalt	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	21300	4260	48.7	87	I ind et al Manuscrint
Ages (Adamydomons sp.)Ages (Manydomons s	Copper	Algae <i>Usterionella japon</i> ica)	Algae	ΜS	25	Cells	105000	10500	74	308 8	
Age (Altorella stilta) Alge (Morella stilta)	Copper	Algae (Chlamydomonas sp.)	Algae	MS	25	Celle	46000	4600	5 7	135.2	
Nger (Duraliella primoleca) Alger (Director) Alger (D	Conner	Alose (Chlorella salina)		10.5	1 4		DOUDT	0001	5 2		
Age Chandinal arritories Answer Symbol	Conner	Algae (Dunaliella nrimolecta)	Aless			Cells	00007	0062	5 .	C.61	
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Age (Hemischin brunescens) Algae SW 25 Cells 188000 18800 18800 352.9 Riby and Rohl Alge (Hemischin brunescens) Algae SW 23 Cells 93000 9300 34 273.5 Riby and Rohl Alge (Hemischin brunescens) Algae SW 25 Cells 93000 9300 34 133.2 Riby and Rohl Alge (Micromonts quantar) Algae SW 25 Cells 95000 34 133.2 Riby and Rohl Alge (Orishodiscus lucher) Algae SW 25 Cells 95000 300 34 133.2 Riby and Rohl Algae (Pseudopedinella pyriformis) Algae SW 25 Cells 2000 2000 34 133.2 Riby and Rohl Algae (Pseudopedinella pyriformis) Algae SW 25 Cells 2000 2000 34 153.3 Riby and Rohl Algae (Pseudopedinella pyriformis) Algae SW 25 Cells 2000 2000 34 153.3 Riby and Rohl Algae Visub	Copper	Algae (Dunaliella fertiolecta)	Algac	SW	25	Cells	57000	5700	34	167.6	
Age Ufencionaris insercers) Age SW 25 Cells 93000 9300 34 273.5 Riey and Roh I Age <i>Heteromatis traginalis</i> Age SW 25 Cells 93000 9300 34 273.5 Riey and Roh I Age <i>Minicromas squama</i> Alge SW 25 Cells 93000 9300 34 273.5 Riey and Roh I Alge <i>Minicros squama</i> Alge SW 25 Cells 93000 9300 34 233.5 Riey and Roh I Alge <i>Phecologium ricornuum</i> Alge SW 25 Cells 52000 5200 34 132.3 Riey and Roh I Alge <i>Phecologicum ricornuum</i> Alge SW 25 Cells 97000 34 35.3 Riey and Roh I Alge <i>Phecologicum ricornuum</i> Alge SW 25 Cells 97000 9700 34 15.3 Riey and Roh I Alge <i>Phecologicum</i>	Copper	Algae (Hemiselmis brunescens)	Algae	SW	25	Cells	188000	18800	34	552.9	-
Ngee (Hercomastit longifilis) Algee SW 25 Cells 21000 2100 34 617.6 Riley and Rohl Algee (Micromastit longifilis) Algee SW 25 Cells 95000 9500 34 279.4 Riley and Rohl Algee (Micromastit longit) Algee SW 25 Cells 6700 4700 34 138.2 Riley and Rohl Algee (Micromast argumatic) Algee SW 25 Cells 6700 6700 34 138.3 Riley and Rohl Algee (Micromast argumatic) Algee SW 25 Cells 67000 6700 34 33.3 Riley and Rohl Algee Vhatedorylum ricernium) Algee SW 25 Cells 5300 5300 34 155.9 Riley and Rohl Algee Christoforcus bacillariy Algee SW 25 Cells 53000 5300 34 155.9 Riley and Rohl Algee Christoforcus Statudy Statudy 264.1 Riley and Rohl 1600 Algee Strichococcus bacillariy Algee SW	Copper	Algae (Hemiselmis virescens)	Algae	SW	25	Cells	93000	9300	34	273.5	
Ngae (Morcomons statem)Algae SW25Cells95000950034279.4Riley and Roth IAlgae (Morcomons statem)Algae (Nistochryst interr)Algae SW25Cells4700034138.2Riley and Roth IAlgae (Nistochryst interr)Algae (Nistochryst interr)Algae SW25Cells4700034138.2Riley and Roth IAlgae (Nistochryst interr)Algae (Nistochryst interr)Algae SW25Cells20003418.2Riley and Roth IAlgae (Nistochryst interr)Algae SW25Cells2000303485.3Riley and Roth IAlgae (Nistochryst interr)Algae SW25Cells20003485.3Riley and Roth IAlgae (Nistorecus bacillaris)Algae SW25Cells53003485.3Riley and Roth IAlgae (Nistorecus bacillaris)Algae SW25Cells53003485.3Riley and Roth IAlgae (Nistorecus bacillaris)Algae SW25Cells53003485.3Riley and Roth INiger (Ditylum brightwellit)Algae SW25Cells5300303415.3Riley and Roth IDiatom (Ditylum brightwellit)Algae SW14Cells70003003013.415.5Camerford et al.Diatom (Ditylum brightwellit)Algae SW14Cells700020010013.313.413.3Bani I (at al.Diatom (Ditylum brightwellit) <td>Copper</td> <td>Algae (Heteromastix longifillis)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>210000</td> <td>21000</td> <td>34</td> <td>617.6</td> <td></td>	Copper	Algae (Heteromastix longifillis)	Algae	SW	25	Cells	210000	21000	34	617.6	
Agee Wonochrysis lunkeri) Algee SW 25 Cells 47000 4700 34 138.2 Riley and Roth 1 Algee (Distructurus) Algee (Distructurus) Algee (Station in triormutum) 34 138.2 Riley and Roth 1 Algee (Distructurus) Algee Station in triormutum) Algee SW 25 Cells 52000 5200 34 138.2 Riley and Roth 1 Algee Greatederilla pryformic) Algee SW 25 Cells 53000 300 34 135.5 Riley and Roth 1 Algee Greatederilla pryformic) Algee SW 25 Cells 53000 5300 34 155.5 Riley and Roth 1 Algee Greatederilla Nigee Greatederilla Nigee Greatederilla 34 155.5 Riley and Roth 1 Algee Greatederil Algee SW 14 Cells 5000 500 34 155.5 Riley and Roth 1 Diatom (Diytum brightwellit) Algee SW 14 Cells 25000 500 200 200 200 200 200 201 105.0 Diatom (Diytum brightwellit) Algee SW 14 Cells	Copper	Algae (Micromonas squamata)	Algae	SΨ	25	Cells	95000	9500	34	279.4	
Algae (Ofisihodiscus lureus)AlgaeSW25Cells62000620034182.4Riley and RohlAlgae (Phaeodocylum ricornutum)AlgaeSW25Cells1100001100003432.3Riley and RohlAlgae (Phaeodocylum ricornutum)AlgaeSW25Cells50003003485.3Riley and RohlAlgae (Frazenitis terahelta)AlgaeSW25Cells500030034155.9Riley and RohlAlgae Gichococus bacillaris)AlgaeSW25Cells5000500034155.9Riley and RohlAlgae Gichococus bacillaris)AlgaeSW14Cells5000500034155.9Riley and RohlDiatom (Diylum brighwelli)AlgaeSW14Cells250002500200200200125.0Canterford et al.Diatom (Diylum brightwelli)AlgaeSW14Cells20000600060010600.0600.0600.0600.0Diatom (Diylum brightwelli)AlgaeSW14Cells2500025000200297.5Canterford et al.Diatom (Diylum brightwelli)AlgaeSW14Cells70000700071.0Canterford et al.Diatom (Diylum brightwelli)AlgaeSW14Cells7100071.071.0Canterford et al.Diatom (Diylum brightwelli)AlgaeSW14Cells7100071.0 <td>Copper</td> <td>Algae (Monochrysis lutheri)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>47000</td> <td>4700</td> <td>34</td> <td>138.2</td> <td></td>	Copper	Algae (Monochrysis lutheri)	Algae	SW	25	Cells	47000	4700	34	138.2	
Algae Phacedacylum tricornutum)Algae SW25Cells11000011000034333.5Riley and RohlAlgae Useudopedinella pyrifornis)Algae SW25Cells290003435.3Riley and RohlAlgae Useudopedinella pyrifornis)Algae SW25Cells530003435.3Riley and RohlAlgae Useudopedinella pyrifornis)Algae SW25Cells530003435.9Riley and RohlAlgae Grichococcus bacillaris)Algae SW25Cells530003435.9Riley and RohlAlgae Grichococcus bacillaris)Algae SW25Cells5300034264.7Riley and RohlDiatom (Diptum brightwellit)Algae SW14Cells2500020008087.5Canterford et al.Diatom (Diptum brightwellit)Algae SW14Cells7000070008087.5Canterford et al.Diatom (Diptum brightwellit)Algae SW14Cells7000070008087.5Canterford et al.Diatom (Diptum brightwellit)Algae SW14Cells70000700071.071.071.0Diatom (Diptum brightwellit)Algae SW14Cells7100071.071.071.071.0Diatom (Diptum brightwellit)Algae SW14Cells7100071.071.071.071.0Diatom (Diptum brightwellit)Algae SW14Cells71.00071.071.071.071.0 </td <td>Copper</td> <td>Algae (Olisthodiscus luteus)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>62000</td> <td>6200</td> <td>34</td> <td>182.4</td> <td></td>	Copper	Algae (Olisthodiscus luteus)	Algae	SW	25	Cells	62000	6200	34	182.4	
Algae <i>Freudopedinella pyrifornis</i>) Algae Sw 25 Cells 29000 2900 34 85.3 Riley and Rohl Algae <i>Sitchococcus bacillaris</i>) Algae Sw 25 Cells 53000 5300 34 155.9 Riley and Rohl Algae <i>Sitchococcus bacillaris</i>) Algae Sw 25 Cells 53000 300 34 155.9 Riley and Rohl Algae <i>Grenoscus bacillaris</i>) Algae Sw 25 Cells 90000 9000 34 264.7 Riley and Rohl Diatom <i>Ditylum brighwellit</i>) Algae Sw 14 Cells 50000 2000 200 20 29 264.7 Riley and Rohl Diatom <i>Ditylum brighwellit</i>) Algae Sw 14 Cells Cells 25000 200 20 20 2125.0 Canterford et al. Diatom <i>Ditylum brighwellit</i>) Algae Sw 14 Cells Cells 70000 7000 80.0 200.0 200.0 200.0 200.0 201.0 264.7 Riley and Rohl Diatom <i>Ditylum brighwellit</i>) Algae Sw 14 Cells Cells 70000 7000 70.0 710 710 710 710	Copper	Algae (Phaeodactylum tricornutum)	Algae	SW	25	Cells	110000	11000	34	323.5	_
Algae Sichococcus bacillaris)AlgaeSW25Cells5300530034155.9Riley and RothAlgae (Teraseimis terranket)Algae SW25Cells90000900034264.7Riley and RothDiatom (Ditylum brightwelli)Algae SW14Cells55000500060006000Canterford et al.Diatom (Ditylum brightwelli)Algae SW14Cells2500020020125.0Canterford et al.Diatom (Ditylum brightwelli)Algae SW14Cells7000070008087.5Canterford et al.Diatom (Ditylum brightwelli)Algae SW14Cells7000070008087.5Canterford et al.Diatom (Ditylum brightwelli)Algae SW14Cells70000710071.071.071.0Diatom (Ditylum brightwelli)Algae SW14Cells700005003330.151.6Diatom (Ditylum brightwelli)Algae SW14Cells70000700080.071.071.0Diatom (Ditylum brightwelli)Algae SW14Cells7000050003330.155.6Buegill (Lepomiz macrochinz)FihFWBain29000500320.080.080.0Buegill (Lepomiz macrochinz)Fish FWGill3000600060071.071.071.0Buegill (Lepomiz macrochinz)Fish FWGill3000600071.070.0	Copper	Algae (Pseudopedinella pyriformis)	Algae	SW	25	Cells	29000	2900	34	85.3	Riley and Roth 1971
Algae (Terraseinis terrarhet.) Algae SW 25 Cells 90000 9000 34 264.7 Riley and Roht Diatom (Ditylum brightwelli) Algae SW 14 Cells 60000 6000 10 600.0 Canterford et al. Diatom (Ditylum brightwelli) Algae SW 14 Cells 25000 200 20 125.0 Canterford et al. Diatom (Ditylum brightwelli) Algae SW 14 Cells 70000 7000 80 87.5 Canterford et al. Diatom (Ditylum brightwelli) Algae SW 14 Cells 70000 7000 80 87.5 Canterford et al. Diatom (Ditylum brightwelli) Algae SW 14 Cells 71000 71.0 00 71.0 <t< td=""><td>Copper</td><td>Algae (Stichococcus bacillaris)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>53000</td><td>5300</td><td>34</td><td>155.9</td><td></td></t<>	Copper	Algae (Stichococcus bacillaris)	Algae	SW	25	Cells	53000	5300	34	155.9	
Diatom (Ditylum brightwelli)AlgaeSW14Cells600060010600.0Canterford et al.Diatom (Ditylum brightwelli)AlgaeSW14Cells2500025020125.0Canterford et al.Diatom (Ditylum brightwelli)AlgaeSW14Cells25000201060.0Canterford et al.Diatom (Ditylum brightwelli)AlgaeSW14Cells7000070008087.5Canterford et al.Diatom (Ditylum brightwelli)AlgaeSW14Cells7100071.0071.0071.0Diatom (Ditylum brightwelli)AlgaeSW14Cells70000600060071.07.0Diatom (Ditylum brightwelli)AlgaeSW14Cells7100071.0071.0071.0Diatom (Ditylum brightwelli)AlgaeSW14Cells7100071.0071.07.07.0Bluegill (Lepomit macrochinz)FishFWBlain2900058003290.0800.0600.0600.0Bluegill (Lepomit macrochinz)FishFWGill300060071.07.07.07.07.0Bluegill (Lepomit macrochinz)FishFWGill30006007.17.07.07.07.07.0Bluegill (Lepomit macrochinz)FishFWGill30006007.17.07.07.07.07.0 </td <td>Copper</td> <td>Algae (Tetraseimis tetrathele)</td> <td>Algae</td> <td>ΝS</td> <td>25</td> <td>Cells</td> <td>00006</td> <td>0006</td> <td>34</td> <td>264.7</td> <td></td>	Copper	Algae (Tetraseimis tetrathele)	Algae	ΝS	25	Cells	00006	0006	34	264.7	
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Diatom (Dirytum brightwellit) Algae SW 14 Cells 40000 50 80.0 Canterford et al. Diatom (Dirytum brightwellit) Algae SW 14 Cells 70000 7000 80 87.5 Canterford et al. Diatom (Dirytum brightwellit) Algae SW 14 Cells 71000 71.0 00 71.0 Canterford et al. Diatom (Dirytum brightwellit) Algae SW 14 Cells 71000 71.0 100 71.0 Canterford et al. Diatom (Dirytum brightwellit) Algae SW 14 Cells 71000 71.0 100 71.0 Canterford et al. Diatom (Dirytum brightwellit) Algae SW 14 Cells 60000 6000 70.0 80.0 7.0 7.0 10.0 71.0 Canterford et al. 193.3 Benoit 1975 Bluegill (Lepomix macrochinus) Fish FW Gill 3000 600 3 20.0 80.0 86.0 3	Copper	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	25000	2500	20	125.0	-
Diatom (Dirylum brightwellit) Algae SW 14 Cells 70000 7000 87.5 Canterford et al. Diatom (Dirylum brightwellit) Algae SW 14 Cells 71000 71.0 00 71.0 Canterford et al. Diatom (Dirylum brightwellit) Algae SW 14 Cells 71000 71.0 00 71.0 Canterford et al. Diatom (Dirylum brightwellit) Algae SW 14 Cells 60000 6000 70.0 70.0 71.0 Canterford et al. Bluegill (Lepomix macrochirus) Fish FW Brain 29000 5800 3 1933.3 Benoit 1975 Bluegill (Lepomix macrochirus) Fish FW Gill 3000 600 12 7.0	Copper	Diatom (Dity-lum brightwellii)	Algae	SW	14	Cells	40000	4000	20	80.0	-
Diatom (Dirylum brightwelli) Algae SW 14 Cells 7100 71.0 Canterford et al. Diatom (Dirylum brightwelli) Algae SW 14 Cells 60000 6000 150 40.0 Canterford et al. Bluegill (Lepomix macrochirus) Fish FW Brain 29000 5800 3 1933.3 Benoit 1975 Bluegill (Lepomix macrochirus) Fish FW Gill 3000 600 12 0.0 8enoit 1975 Bluegill (Lepomix macrochirus) Fish FW Gill 3000 600 12 50.0 Benoit 1975 Bluegill (Lepomix macrochirus) Fish FW Gill 3000 600 12 50.0 Benoit 1975 Bluegill (Lepomix macrochirus) Fish FW Gill 3000 600 12 50.0 86.0 3 26.0 3 26.0 3 26.0 3 36.0 3 36.0 3 36.0 3 36.0 36.0 36.0 <td>Copper</td> <td>Diatom (Ditylum brightwellii)</td> <td>Algae</td> <td>SW</td> <td>14</td> <td>Cells</td> <td>70000</td> <td>7000</td> <td>80</td> <td>87.5</td> <td>-</td>	Copper	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	70000	7000	80	87.5	-
Diatom (Ditylum brightwellii)AlgaeSW14Cells60000600015040.0Canterford et al.Bluegil (Lepomis macrochins)FishFWBrain29000580031933.3Benoit 1975Bluegil (Lepomis macrochins)FishFWGill30006003200.0Benoit 1975Bluegil (Lepomis macrochins)FishFWGill30006001250.0Benoit 1975Bluegil (Lepomis macrochins)FishFWGill30006001250.0Benoit 1975Bluegil (Lepomis macrochins)FishFWGill30006001256.0Benoit 1975	Copper	Diatom (Ditylum brightwellii)	Algae	ΝS	14	Cells	71000	7100	001	71.0	
Bluegill (Lepomis macrochirus) Fish FW Brain 29000 5800 3 1933.3 Benoit 1975 Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 3 200.0 Benoit 1975 Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 12 50.0 Benoit 1975 Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 12 56.0 3	Copper	Diatom (Ditylum brightwellii)	Algae	SW	14	Cells	60009	6000	150	40.0	Canterford et al.
Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 3 200.0 1 Bluegil (Lepomis macrochirus) Fish FW Gill 3000 600 12 50.0 1 Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 21 28.6 1	Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Brain	29000	5800	F	1933.3	Benoit 1975
Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 12 50.0 Bluegill (Lepomis macrochirus) Fish FW Gill 3000 600 21 28.6	Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Gill	3000	600	•	200.0	
Bluegil (Lepomis macrochirus) Fish FW Gill 3000 600 21 28.6	Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Gill	3000	600	12	50.0	
	Copper	Bluegill (Lepomis macrochirus)	Fish	ΕW		115	0001	007	ł		

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

AR 044665

November 5, 1999

4 - 9

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Metal/Metalloid	Species	Type	Type	Uuration (days)	Tissue	t issue (μg/kg-dry)	1 ISSUE (μg/kg-wet)	Water (µg/L)	BCF	Reference
Copper	Bluegili (Lepomis macrochirus)	Fish	FΨ		Gill	5000	1000	40	25.0	Benuit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Gill	0009	1200	77	15.6	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Gonad	5000	1000	3	333.3	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Kidney	22000	4400	E	1466.7	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Kidney	0006	1800	12	150.0	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Kidney	12000	2400	21	114.3	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Kidney	13000	2600	40	65.0	Bennit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Kidney	12000	2400	11	31.2	Benuit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Liver	2000	1400	**1	466.7	Bennit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Liver	8000	1600	12	133.3	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Liver	10000	2000	21	95.2	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Liver	61000	12200	40	305.0	Renoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Liver	57000	11400	T.	148.1	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Muscle	0001	200		66.7	Benoit 1975
Copper	Bluegill (Lepomis macrochirus)	Fish	FW		Spleen	18000	3600		1200.0	
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Cill	3800	760	3.4	2235	
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Gill	4300	860	6.5	132.3	Brunes et al 1973
Copper	Brown builhead Uctalurus nebulosus)	Fish	FW		Gill	4300	860	01	86.0	Brines et al 1973
Copper	Brown builhead Uctaturus nebulosus)	Fish	FW		Gill	3600	720	16	45.0	
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Gill	0069	1380	27	51.1	Brungs et al. 1973
Copper	Brown bullhead Uctaturus nebulosus)	Fish	FW		Gill	25000	5000	51	98.0	Brungs et al. 1973
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Kidney	7800	1560	3.4	458.8	Brungs et al. 1973
Copper	Brown hullhead Uctalurus nebulosus)	Fish	FW		Kidney	8500	1700	6.5	261.5	Brungs et al. 1973
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Kidney	8800	1760	10	176.0	Brungs et al. 1973
Copper	Brown bullhead <i>Uctalurus nebulosus</i>)	Fish	FW		Kidney	14300	2860	91	178.8	Brungs et al. 1973
Copper	Brown bullhead Vctalurus nebulosus)	Fish	FW		Kidney	10000	2000	27	74.1	Brungs et al. 1973
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FΨ		Liver	29000	5800	3.4	1705.9	
Copper	Brown bullhead Uctalurus nebulosus)	Fish	FW		Liver	28000	5600	6.5	861.5	
Copper	Brown builhead Uctalurus nebulosus)	Fish	FW		Liver	32000	6400	10	640.0	
Copper	Brown builhead (Ictalurus nebulosus)	Fish	FW		Liver	47000	9400	16	587.5	Brungs et al. 1973
Copper	Brown builthead Uctalurus nebulosus)	Fish	FW		Liver	61000	12200	27	451.9	Brungs et al. 1973
Copper	Brown bullbead Uctalurus nebulosus)	Fish	FW		Liver	130000	26000	51	509.8	Brungs et al. 1973
Copper	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	00911	2320	Ś	464	Lind et al. Manuscript
Copper	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	19800	3960	6	440	Lind et al. Manuscript
Copper	Stone loach (Noemacheilus barbatulus)	Fish	FW	63	Liver	77000	15400	120	128.3	Solbe and Cooper 1976
Copper	Stone loach (Noemacheilus barbatulus)	Fish	FW	63	Muscle	10100	2020	120	16.8	Solbe and Cooper 1976
Copper	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	540000	108000	01	10800.0	Ahsanulla and Williams 1991
Copper	Amphipod (Hyalella azteca)	Invert	FW	70	WB	19000	15800	3.5	4514.3	-
Copper	Amphipod (Hyalella azteca)	Invert	FW	70	WB	00016	18200	1.1	2363.6	_

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

01 - V

AR 044666

		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Type	Type	(days)	Tissue	(Jug/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(J/B/J)	BCF	Reference
Copper	Amphipod (Hyalella azteca)	Invert	FW	70	WR	04000	tonno	167	11377	Boremann of all 1003
Copper	Amphipod (Hyalella azteca)	Invert	ΕW	28	WB	000111	22200	50.5	C C 6 6	Boremann and Normood 1005
Copper	Amphipod (Ityalella azteca)	Invert	FW	42	WB	000111	22200	50.5	447 7	Boremann and Normood 1006
Copper	Asiatic clam (Corbicula fluminae)	Invert	FW	28	Soft parts	055955	55952	191	1370.9	Cranevet al 1083
Copper	Asiatic clam (Corbicula fluminae)	Invert	FW	28	Soft parts	774500	77450	2 5	1358.8	Grameviet al 1083
Copper	Bay scallop (Argopecten irradians)	Invert	SW	56	Soft parts	28000	2800	18.1	1547.0	Zaroogian and Johnson 1983
Copper	Bay scallop (Argopecten irradians)	Invert	SW	56	Soft parts	00016	9100	4.56	1995.6	Zaroogian and Johnson 1983
Copper	Bay scallop (Argopecten irradians)	Invert	SW	56	Soft parts	310000	31000	10.24	3027.3	Zaroogian and Johnson 1983
Copper	Blue mussel (Mytilus edulis)	Invert	ΜS	35	Soft parts	2593	350	01	35.0	Phillips 1976
Copper	Blue mussel (Mytilus edulis)	Invert	ΜS	35	Soft parts	10222	1380	50	69.0	Phillips 1976
Copper	Blue mussel (Myrilus edulis)	Invert	ΝS	35	Soft parts	54963	7420	40	185.5	Phillins 1976
Copper	Blue mussel (Mytilus edulis)	Invert	ΜS	35	Soft parts	3926	530	20	26.5	Phillips 1976
Copper	Blue mussel (Mytilus edulis)	Invert	SW	630	Soft parts	5510	551	1.0	551.0	Calabrese et al 1984
Copper	Blue mussel (Mytilus edulis)	Invert	SW	630	Soft parts	0/161	1917	5.0	383.4	Calabrese et al. 1984
Copper	Blue mussel (Mytilus edulis)	Invert	ΜS	630	Soft parts	62030	6203	10.0	620.3	Calabrese et al. 1984
Copper	Cladoc era n (Daphnia magna)	Invert	FW	7	WB	70.7	14.14	30	0.5	Winner 1984
Copper	Cladoceran (Daphnia magna)	Invert	FW	7	WB	67.3	13.46	30	0.4	Winner 1984
Copper	Hard clam (Mercenaria mercenaria)	Invert	ΜS		I	1	I	I	88	USEPA 1985d
Copper	Soft-shell clam (Mya arenaria)	Invent	SW		ı	I	I	I	3,300	USEPA 1985d
Copper	Clam (Protothaca staminea)	Invert	SW	30	Gill	35300	3530	7	504.3	Roesiiadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Gill	109500	10950	18	608.3	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Kidney	111100	01111	7	1587.1	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	ΝS	30	Kidney	27200	2720	8	151.1	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Muscle	34700	3470	7	495.7	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Muscle	35000	3500	81	194.4	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Viscera	57700	5770	7	824.3	Ro cs ijadi 1980
Copper	Clam (Protothaca staminea)	Invert	SW	30	Viscera	54500	5450	18	302.8	Rocsijadi 1980
Copper	Clam (Protothaca staminea)	Invert	ΝS	30	WB	47700	4770	7	681.4	Roesijadi 1980
Copper	Clam (Protothaca staminea)	Invert	ΝS	30	WB	46700	4670	18	259.4	Roesijadi 1980
Copper	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	I	694800	25	27792.0	Shuster and Pringle 1969
Copper	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	I	715600	25	28624.0	Shuster and Pringle 1969
Copper	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	1	1125000	50	22500.0	
Copper	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft parts	1	943800	50	18876.0	
Copper	Isopod Asellus meridianus)	Invert	FW	14	WB	80000	160000	500	320.0	Brown 1977
Copper	lsopod (Asellus meridianus)	Invert	FW	14	WB	80000	1 60000	500	320.0	Brown 1977
Copper	lsopod Asellus meridianus)	Invert	FW	14	WB	260000	520000	500	1040.0	Brown 1977
Copper	Polychaete (Phyllodoce maculata)	Invert	ΝS	21	WB	164140	45466.78	01	4546.7	McLusky and Phillips 1975
Copper	Polychaete (Phyllodoce maculata)	Invert	ΝS	21	ŴВ	260160	72064.32	20	3603.2	
Copper	Polychaete (Phyllodoce maculata)	Invert	sw	21	WB	364650	101008.05	30	3366.9	_
Copper	Polychaete (Phyllodoce maculata)	Invert	δW	21	WB	321430	89036.11	40	2225.9	

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

11 - V

MetholetalistSpeiceTyp			Type Invert Invert Invert Invert Invert Invert	Type SW cw	(days)	Tissue	(µg/kg-dry)	(µg/kg-wet)	(hg/L)	BCF	Reference
Polychase (Phylodec modula) Iner SW 21 WB 56530 15523.81 9 1345 Polychase (Phylodec modula) Iner SW 21 WB 56630 15230.65 6 22.33 Polychase (Phylodec modula) Iner SW 29 WB 5600 12301.55 9 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383 1383		maculata) maculata) maculata) ancouveri) ancouveri) ancouveri) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	liwert Invert Invert Invert Invert Invert	MS	7	1	67,630			9 8615	
Physical (Pricing) Inert SW 21 WB 56680 195283 9 221314 Physical (Pricing) wancowort) Inert SW 21 WB 67900 132673 0 13893 1 Physical (Editriplic vancomer) Inert SW 29 WB 67900 132673 0 13893 1 Physical (Editriplic vancomer) Inert SW 29 WB 67000 132673 0 13893 1 <		maculata) maculata) maculata) ancouveri) ancouveri) ancouveri) ancouveri) ancouveri) a polymorpha) a polymorpha) a polymorpha)	livert Invert Invert Invert Invert Invert Invert	SW SW	į	C 111	000000			2128 G	
		maculata) maculata) ancouveri) ancouveri) ancouveri) a polymorpha) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert Invert Invert Invert Invert Invert	C W	17	WB	000000	156928.81	50	0.0010	McLusky and Phillips 1975
Projectater Energiation SW 21 VB 47750 13267.5 70 1389.5 Projectater Exclusion(an surrower) Insert SW 29 VB 6000 1326.5 70 1328.5 70 71 70 71 70 71 70 71 71 71 71 71 71 71		maculata) ancouveri) ancouveri) ancouveri) ancouveri) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert Invert Invert Invert Invert	24	21	WB	567800	157280.6	60	2621.3	McLusky and Phillips 1975
Polyahate (Endipolita vanconer) Inert SW 29 VB 6400 1200 104 2120 Polyahate (Endipolita vanconer) Inert SW 29 VB 900 100 101 1200 104 1200 Polyahate (Endipolita vanconer) Inert SW 29 VB 1000 100 101 1200 1010 101 1200 1200 1200 1200 1200 1200 1200 1200		ancouveri) ancouveri) ancouveri) ancouveri) enaceodentata) spirabranchia) a polymorpha) a polymorpha) a polymorpha)	Invert Invert Invert Invert Invert	SW	21	WB	477500	132267.5	20	1889.5	McLusky and Phillips 1975
Polybrate (<i>diarbitis vanceneri</i>) Inset SW 29 WB 4000 2960 3162 2009 3163 9109 Polybate (<i>diarbity vanceneri</i>) Inset SW 29 WB 4000 2960 3163 9013 Polybate (<i>diarbity vanceneri</i>) Inset SW 29 WB 2000 2000 316 9103 Polybate (<i>finarbity vanceneri</i>) Inset FW 77 S61 WB 2000 113 041 2000 316 2001 317 317 Zehn musel (<i>Dreiteren polymerpha</i>) Inset FW 77 S61 PN 317		ancouveri) ancouveri) ancouveri) enaceodentata) spirabranchia) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert Invert Invert Invert	SW	29	WB	6400	1280	0.14	9142.9	Young et al. 1979
Polychete (Eutropic surroutor) Inset SW 29 WB 1/100 230 325 9013 Polychete (Eutropic surroutor) Inset SW 29 WB 3900 119 3900 135 3901 13 3913 Polychete (Eutropic surroutor) Inset SW 29 WB 3900 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 333 3930 13 333 3930 13 333 3930 13 333 3930 13 333 3930 13 333 3930 13 3333 3930 13 333 3930 13 3333 3930 13 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333 3333		ancouveri) ancouveri) enaceodentata) spirabranchia) s polymorpha) s polymorpha) s polymorpha) s polymorpha)	lnvert Invert Invert Invert	SW	29	WB	9800	1960	1.62	1209.9	Young et al. 1979
Polychete (<i>Entification transformeric)</i> Inset SW 23 000 640 625 646 750 Polychete (<i>Entification syntheration</i>) Inset SW 23 WB 300 118 001 300 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3930 13 3331 3331 3331 3331 3331 3331 3331 3331 3331 3331 3331 3331 3331 3331 3311		ancouveri) enaceodentata) spirabranchia) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert Invert Invert	SW	29	WB	14700	2940	3.26	901.8	Young et al. 1979
Polychate (<i>Periformis priorbenchans</i>) lower SW 230 118 004 2300 113 014 2300 113 014 2300 113 014 2300 113 014 2300 113 014 2300 2001		enaceodentata) spirabranchia) a polymorpha) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert Invert	SW	29	WB	30200	6040	6.26	964.9	Young et al. 1979
Polynetic (<i>Trifornia gradinarchia</i>) Iner SW 24 2000 10400 30 3000 10400 30 3000		spirabranchia) a polymorpha) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert	SW	28	WB	590	118	0.04	2950.0	Pesch and Morgan 1978
Zehn nussel ($Dreixenta polymorpha) Inert FW 77 Sch parts 11000 2100 3 7000 N Zehn nussel (Dreixenta polymorpha) Inert FW 77 Sch parts 10000 2100 3 3135 K Zehn nussel (Dreixenta polymorpha) Inert FW 65 Sch parts 10000 2100 3 3133 X Zehn nussel (Dreixenta polymorpha) Inert FW 63 Sch parts 10000 2100 3 3133 X Zehn nussel (Dreixenta polymorpha) Inert FW 63 Sch parts 10000 2100 3 3133 X Zehn nussel (Dreixenta polymorpha) Inert FW 63 Sch parts 200000 2000 3 3133 X Alge (Zehnychenta) Inert FW 23 Sch parts 20000 2000 3 3133 X Alge (Zehnychenta) Inert FW 23 Sch part 20000 5000 <$		a polymorpha) a polymorpha) a polymorpha) a polymorpha) a polymorpha)		SW	24	WB	52000	10400	40	260.0	Millanovich et al. 1976
Transmer Differences Differences <thdifferences< th=""> <thdifferences< th=""> <</thdifferences<></thdifferences<>		a polymorpha) a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert	FW	11	Soft parts	21000	2100	e	700.0	Kraak et al. 1992
Zeha musel (<i>Dreisena polymorpha</i>) Inert FW 63 Soft parts 16000 16000 3 5333 K Zeha musel (<i>Dreisena polymorpha</i>) Invert FW 63 Soft parts 200000 30000 3 3333 Zeha musel (<i>Dreisena polymorpha</i>) Invert FW 63 Soft parts 200000 30000 3 3333 Zeha musel (<i>Dreisena polymorpha</i>) Invert FW 63 Soft parts 200000 20000 3 3333 Zeha musel (<i>Dreisena polymorpha</i>) Invert FW 63 Soft parts 200000 3000 313 335 Alge (<i>Drusiding traviocca</i>) Alge SW 25 Cells 8100 810 311 335 Alge (<i>Hensidinit traviocca</i>) Alge SW 25 Cells 8100 810 311 335 Alge (<i>Hensidinit traviocca</i>) Alge SW 25 Cells 3100 310 312 312 Alge (<i>Hensidinit traviocca</i>) Alge SW 25 Ce		a polymorpha) a polymorpha) a polymorpha) a polymorpha)	Invert	FW	11	Soft parts	00081	1800	13	138.5	Kraak et al. 1992
Zehn musel (Dreitsren $p()morpha)$ Inert FW 63 Soft parts 20000 33 3174 8 Zehn musel (Dreitsren $p()morpha)$ Inert FW 63 Soft parts 20000 300 33 3174 8 Zehn musel (Dreitsren $p()morpha)$ Inert FW 63 Soft parts 20000 31 333 N Agastic moss (bf)mchostregium ripariodics) Name View 25 Cells 11000 110 31 335 A Agast (Drainding rimolecan) Agast SW 25 Cells 11000 110 31 335 A Agast (Drainding rimolecan) Agast SW 25 Cells 11000 110 31 335 A 332 332 344 332 3 342 3 332 3 344 3 332 3 344 3 332 3 332 3 344 3 332 3 344 3 33		a polymorpha) a polymorpha) a polymorpha)	Invert	FW	63	Soft parts	16000	1600	•	533.3	Kraak et al. 1992
Zehn musses (<i>Dreisens polymorpha</i>) Inset FW 63 Soft parts 20000 2000 23 2373 R Zehn musses (<i>Dreisens polymorpha</i>) Inset FW 63 Soft parts 40000 4000 72 2373 R Agae (<i>Chamydomens s</i> p) 1000 110 31 333 R Agae (<i>Chamydomens s</i> p) Agae (<i>Sumoutidu treiders</i>) Agae (<i>Chamydomens s</i> p) Agae (<i>Chamydomens s</i> p) 1000 110 31 333 R Agae (<i>Merconnas squamid</i>) Agae (<i>Sumoutidu treiders</i>) Agae (<i>Sumoutidu treiders</i>) Agae (<i>Sumoutidu treiders</i>) 1100 1100 31 333 R Agae (<i>Merconnas squamid</i>) Agae (<i>Sumoutidu treiders</i>) Agae (<i>Sumoutidu treiders</i>) Agae (<i>Sumoutidu treiders</i>) 31 32 21 31 32 21 31 32 21 31 32 21 32 21 32 21 32 21 32 21 31		a polymorpha) a polymorpha)	Invert	FW	63	Soft parts	20000	20000	53	377.4	Kraak et al. 1992
Zohn nussel (<i>Dreticena polymorpha</i>) Inver FW 63 Soh parts 00000 40000 90 4444 R Aquati: rows (<i>Prychologien</i>) Pant FW 27 WB 180000 80000 310 355 F Agree (<i>Chanodemuss sp.</i>) Agree SW 25 Cells 180000 8000 310 313 355 F Agree (<i>Chanodemuss sp.</i>) Agree SW 25 Cells 180000 8000 31 355 F Agree (<i>Hermicula trifoleca</i>) 31 550 31 355 F Agree (<i>Hermicula trifoleca</i>) 31 550 31 355 F Agree (<i>Hermicula trifoleca</i>) 31 500 31 132 51 7 2 F Agree (<i>Hermicula trifoleca</i>) 31 56 31 32 F Agree (<i>Hermicula triforeca</i>) 31 54 7 32 2 2 13 14 7 32 32 2 13 14 13		a polymorpha)	Invert	FW	63	Soft parts	20000	20000	72	277.8	Kraak et al. 1992
Aquatic moss $dhynchostegium riporioties Plant FW 27 WB 1800000 116 81333 A Algee (Minchostegium riporioties) 31 335 5 Algee (Minchostegium riporioties) Algee SW 25 Cells 16000 1100 31 332 5 Algee (Minchostegium riporioties) Algee SW 25 Cells 56000 5600 31 332 5 Algee Minchostegium riporioties) Algee SW 25 Cells 21200 2120 31 1032 7 Algee Minchostegium riporioties) Algee SW 25 Cells 21200 2120 31 1032 7 7 Algee Minchostegium riporioties) Algee SW 25 Cells 21200 2120 31 1033 11 1033 Algee Minchostegium riporioties) Algee SW 25 Cells 21200 2120$			Invert	FW	63	Soft parts	40000	40000	8	444.4	Kraak et al. 1992
Alge (Alamydomona sp.) Alge SV 25 Cells 11000 1100 31 33.5 R Alge (Dundided retrioleca) Alge (Dundided retrioleca) Alge (Dundided retrioleca) Alge (Dundided retrioleca) 31 33.2 33.2 33.2 33.2		stegium riparioides)	Plant	FW	27	WB	1800000	180000	21.6	8333.3	Mersch et al. 1993
Algae (Duratiefla primofecta) Al		sp.)	Algae	SW	25	Cells	11000	1100	31	35.5	Riley and Roth 1971
Ager (Duraliella terrioleca) Ager (Duraliella terrioleca) Ager (Duraliella terrioleca) Ager (Duraliella terrioleca) Ager (Hermischnis bringhtlits) Ager (Hermischnis verscens) Alger SW 25 Cells 5500 560 310 311 28.1 5 Ager (Hermischnis bringhtlits) Alger SW 25 Cells 5500 560 311 103.2 F Alger (Micromona squamata) Alger SW 25 Cells 5000 300 311 103.2 F Alger (Micromona squamata) Alger SW 25 Cells 21200 2120 31 103.2 F Alger (Micromona squamata) Alger SW 25 Cells 21200 210 31 103.2 F <td></td> <td>olecta)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>16500</td> <td>1650</td> <td>31</td> <td>53.2</td> <td>Riley and Roth 1971</td>		olecta)	Algae	SW	25	Cells	16500	1650	31	53.2	Riley and Roth 1971
Age (Hemicelmis hrunescens) Age SW 25 Cells 5500 550 31 182.3 R Age (Hemischnis vrescens) Age SW 25 Cells 5500 31 182.3 F Age (Hemischnis vrescens) Age SW 25 Cells 3000 300 31 101.2 F Age (Monochysis luther) Age SW 25 Cells 21000 200 31 61.3 F F 7 F 7 F 7 F 7 F 7 F 7 F 7 F 7 F 7 F 7 F 7		lecta)	Algae	SW	25	Cells	8100	810	31	26.1	Riley and Roth 1971
Age Utensient vicesces Alge Vienselmis Alge Viense		lescens)	Algae	SW	25	Cells	56500	5650	31	182.3	Riley and Roth 1971
Algae (Hereromatric longifilis) Algae SW 25 Cells 5000 5000 31 161.3 F Algae (Monochrysis lutheri) Algae SW 25 Cells 21200 2120 31 661.3 F Algae (Monochrysis lutheri) Algae SW 25 Cells 21200 2120 31 1693.4 F Algae (Preadopedinella pryformis) Algae SW 25 Cells 2000 2000 31 1693.4 F Algae (Sichococcus bacillary) Algae SW 25 Cells 12000 1200 31 655 T Diatom (Ditylum brighwellit) Algae SW 14 Cells 10000 1000 2000 200 200 25 6000 201 1 37 1 37 1 37 1 37 1 37 1 37 1 37 1 37 1 37 1 37 1 37		icens)	Algae	SW	25	Cells	32000	3200	31	103.2	Riley and Roth 1971
Algae Wicromonas squamata) Algae SW 25 Cells 21200 2120 31 68.4 F Algae Wonochrysis lutheri) Algae SW 25 Cells 9200 920 31 19.4 F Algae Wonochrysis lutheri) Algae SW 25 Cells 9200 9200 31 169.4 F Algae Wichonedia priformics) Algae SW 25 Cells 12000 12000 31 68.4 F Algae Wichonedia Diatom (Dirjum brightwellit) Algae SW 14 Cells 12000 1300 31 65.5 F Diatom (Dirjum brightwellit) Algae SW 14 Cells 100000 10000 5000 500.0 50 00.0 55.5 600.0		ngifillis)	Algae	SW	25	Cells	50000	5000	31	161.3	Riley and Roth 1971
Agae (Monochysis lutheri) Agae SW 25 Cells 9200 920 31 29,1 F Algae (Phaeodocylum ricornuum) Algae SW 25 Cells 46300 4630 31 149.4 F Algae (Strehoorcus bacillaris) Algae Strehoorcus bacillaris) Algae Strehoorcus bacillaris) Algae Strehoorcus bacillaris) 31 149.4 F 337 F F 149.4 F 337 F F 7 F 149.4 F		iamata)	Algae	SW	25	Cells	21200	2120	31	68.4	Riley and Roth 1971
Algae (Phaeodacylum tricornutum) Algae Sw 25 Cells 46300 4630 31 149.4 F Algae (Pseudopedinella pyriformis) Algae Sw 25 Cells 12000 1200 31 38.7 F Algae (Pseudopedinella pyriformis) Algae Sw 25 Cells 12000 1200 31 38.7 F Diatom (Diylum brighrwellit) Algae Sw 14 Cells 12000 12000 31 38.7 F Diatom (Diylum brighrwellit) Algae Sw 14 Cells 100000 10000 500 20 20 20 20 20 20 20 20 20 20 20 20 2		heri)	Algae	SW	25	Cells	9200	920	31	29.7	Riley and Roth 1971
Algae (Pseudopedinella pyriformic) Algae Su SV 25 Cells 12000 1200 31 38.7 F Algae Stichococcus bacillaris) Algae Strichococcus bacillaris) Algae Strichococcus bacillaris) Algae Strichococcus bacillaris) 31 35.5 F 7 31 55.5 F 7 93 1 55.5 F 50.00 15.000 15.000 15.000 15.000 15.000 50.0 55.5 F 50.00 50.0 50.00 50.0 55.5 F 50.00 50.0 50.0 50.0 55.5 F 50.00 150.00 150.00 150.00 150.00 <t< td=""><td></td><td>(ricornutum)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>46300</td><td>4630</td><td>31</td><td>149.4</td><td>Riley and Roth 1971</td></t<>		(ricornutum)	Algae	SW	25	Cells	46300	4630	31	149.4	Riley and Roth 1971
Algae (Srichococcus bacillaris) Algae SW 25 Cells 20300 2030 31 65.5 1 Diatom (Dinylum brightwellit) Algae SW 14 Cells 150000 15000 25 6000 2 Diatom (Dinylum brightwellit) Algae SW 14 Cells 150000 1000 30 23 6000 2 2000 2 2000 2 2000 2 <td< td=""><td></td><td>pyriformis)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>12000</td><td>1200</td><td>31</td><td>38.7</td><td>Riley and Roth 1971</td></td<>		pyriformis)	Algae	SW	25	Cells	12000	1200	31	38.7	Riley and Roth 1971
Diatom (Dirylum brightwellit) Algae SW 14 Cells 150000 15000 25 600.0 C Diatom (Dirylum brightwellit) Algae SW 14 Cells 100000 1000 50 27 600.0 6 Diatom (Dirylum brightwellit) Algae SW 14 Cells 130000 13000 150 86.7 6 200.0 6		cillaris)	Algae	SW	25	Cells	20300	2030	31	65.5	Riley and Roth 1971
Diatom (Dirylum brighrwellit) Algac SW 14 Cells 100000 1000 50 200.0 6 Diatom (Dirylum brighrwellit) Algae SW 14 Cells 80000 8000 100 80.0 60		twellii)	Algae	SW	14	Cells	150000	15000	25	600.0	Canterford et al. 1978
Diatom (Dirytam brightwelfit) Algae SW 14 Cells 80000 8000 100 80.0 6 1 Diatom (Dirytam brightwelfit) Algae SW 14 Cells 130000 13000 150 86.7 6 Diatom (Dirytam brightwelfit) Algae SW 14 Cells 130000 13000 150 86.7 6 Diatom (Dirytam brightwelfit) Algae SW 14 Cells 140000 14000 300 46.7 6 Diatom (Dirytam brightwelfit) Algae SW 14 Cells 150000 1500 300 45.7 6 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 16 44 1 1 8000 1600 310 25 31.9 36 72 0.9 80 1 47 1 1 10 10 10 26 0.9 26 0.9		rwellii)	Algac	SW	14	Cells	100000	10000	20	200.0	Canterford et al. 1978
Diatom (Dirytum brighrwelti) Algae SW 14 Cells 130000 13000 150 86.7 6 Diatom (Dirytum brighrwelti) Algae SW 14 Cells 140000 14000 300 46.7 6 Diatom (Dirytum brighrwelti) Algae SW 14 Cells 140000 14000 300 46.7 6 Diatom (Dirytum brighrwelti) Algae SW 14 Cells 150000 15000 300 46.7 6 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 10 6 7 7 0.9 80 16 47 1 18 800 1600 34 47 1 18 10 10 10 10 10 10 14 17 0 90 10 0 10 0 10 10 10 14 11 10 10 10 10 14 11 10 14 11 10 10 10 11		rwellii)	Algae	SW	14	Cells	80000	8000	001	80.0	Canterford et al. 1978
Diatom (Dirytum brighrwellit) Algae SW 14 Cells 140000 14000 300 46.7 6 Diatom (Dirytum brighrwellit) Algae SW 14 Cells 150000 15000 300 46.7 6 Diatom (Dirytum brighrwellit) Algae SW 14 Cells 150000 15000 500 300 46.7 6 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 18 87 44 17 18 18 18 14 18 14		twellii)	Algae	SW	14	Cells	130000	13000	150	86.7	Canterford et al. 1978
Diatom (Dirytum brightwellit) Algae SW 14 Cells 150000 15000 500 30.0 6 Diatom (Dirytum brightwellit) Algae SW 14 Cells 150000 15000 500 30.0 6 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 1 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 12700 2540 58 44 1 Amphipod (Hjvalella azteca) Invert FW 70 WB 1300 260 0.4 650.0 1.4 131.5 1.4 1		rwellii)	Algae	SW	14	Cells	140000	14000	300	46.7	
Diatom (Dirylum brighwellit) Algae SW 14 Cells 400000 40000 750 53.3 6 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 18 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 12 0.9 80 13 47 18 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 12700 2540 58 44 18 Amphipod (Hjvalella azteca) Invert FW 70 WB 1300 260 0.4 650.0 14.0 15.1.5 1.0 14.0 26.0 0.4 26.0 1.4 15.5 1.0 21.6 24.0 26.0 1.4 15.1.5 1.5 1.0 14.0 2.6 24.6.2 1.3 351.5 1.0 21.6 24.6.2 1.3 351.5 1.0 24.6.2 1.0 26.0 2.6 24.6.2 1.5 1.0 1.00 1.20 2.6 54.5.2 1.5 1.0 2.6		twellii)	Algae	SW	14	Cells	150000	15000	500	30.0	Canterford et al. 1978
Brook trout (Salvelinus fontinalis) Fish FW 90 WB 360 72 0.9 80 1 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 8000 1600 34 47 1 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 8000 1600 34 47 1 Amphipod (Hjvalella azteca) Invert FW 70 WB 1300 260 0.4 650.0 1 Amphipod (Hjvalella azteca) Invert FW 70 WB 3100 260 0.4 650.0 1 Amphipod (Hjvalella azteca) Invert FW 70 WB 7100 1420 2.6 546.2 1		rwellii)	Algae	SW	14	Cells	40000	40000	750	53.3	
Brook trout (Salvelinus fontinalis) Fish FW 90 WB 8000 1600 34 47 1 Brook trout (Salvelinus fontinalis) Fish FW 90 WB 12700 2540 58 44 1 Amphipod (Hyalella azteca) Invert FW 70 WB 1300 260 0.4 650.0 Amphipod (Hyalella azteca) Invert FW 70 WB 5800 1160 3.3 351.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1301.5 1315.5 1301.5 1501.5 1401.5 14		fontinalis)	Fish	FW	96	WB	360	72	0.9	80	
Brook trout (Salvelinus fontinalis) Fish FW 90 WB 12700 2540 58 44 Amphipod (Hyalella azteca) Invert FW 70 WB 1300 260 0.4 650.0 Amphipod (Hyalella azteca) Invert FW 70 WB 5800 1160 3.3 351.5 Amphipod (Hyalella azteca) Invert FW 70 WB 7100 1420 2.6 546.2	-	fontinalis)	Fish	FW	6	WB	8000	1600	34	47	Holcombe et al. 1976
Amphipod (<i>tfyalella azteca</i>) Invert FW 70 WB 1300 260 0.4 650.0 Amphipod (<i>tfyalella azteca</i>) Invert FW 70 WB 5800 1160 3.3 351.5 Amphipod (<i>tfyalella azteca</i>) Invert FW 70 WB 7100 1420 2.6 546.2		fontinalis)	Fish	FW	8	WB	12700	2540	58	44	
Amphipod (thalella azteca) Invert FW 70 WB 5800 1160 3.3 351.5 Amphipod (thalella azteca) Invert FW 70 WB 7100 1420 2.6 546.2	-	teca)	Invert	FW	70	WB	1300	260	0.4	650.0	Borgmann et al.
Amphipod (Hyalella azteca) Invert F.W 70 WB 7100 1420 2.6 546.2		teca)	Invert	FW	70	WB	5800	0911	3.3	351.5	_
		teca)	Invert	FW	70	WB	7100	1420	2.6	546.2	Borgmann et al. 1993

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry) (µg/kg-wet)	(µg/kg-wet)	(hg/L)	BCF	Reference
Lead	Amphipod (Hyalella azteca)	Invert	ΕW	70	WB	1 5800	3160	211		-
Lead	Blue mussel (Mytilus edulis)	lavert	MS	6	Soft narts	00021	DOLE	0.11	4.7/7 7007	Borgmann er al. 1993
Lead	Blue mussel (Mytilus edulis)	Invert	MS	40	Soft parts	00007	0007	n <u>\$</u>	0.000	Schulz-Baides 19/4
Lead	Blue mussel (Mytilus edulis)	Invert	SW	40 40	Soft narts	00009t	36000	25	040.0	Schulz-Baldes 19/4
Lead	Blue mussel (Myrilus edulis)	Invert	MS	40	Soft parts	640000			0.021	Schuiz-Baides 19/4
Lead	Blue mussel (Mytilus edulis)	Invert	MS	ę 4	Soft narts	1400000	140000	3	0.040.0	Schulz-Baides 1974
Lead	Blue mussel (Mytilus edulis)	Invert	MS	4	Soft narts	2500000	000052	8 F	0.00/	Schulz-Baldes 1974
Lead	Blue mussel (Mytilus edulis)	Invert	MS	9 1 1	Soft parts	0000005	000003	000	0.000	Schulz-Baldes 19/4
Lead	Blue mussel (Mytilus edulis)	Invert	MS	2 4	Soft narts	1 RODOOD			0.000	Schuiz-Baides 19/4
Lead	Blue mussel (Mytilus edulis)	Invert	MS	011	Soft narts	1 2840000			0.000	Schulz-Baides 1974
Lead	Blue mussel (Mytilus edulis)	Invert	SW	130	Soft narts	00002210	2077000		0.0002	Schulz-Baides 1972
Lead	Blue mussel (Mytilus edulis)	Invert	MS	130	Soft narts	30830000	0001107		107 202	Schulz-Baldes 1972 Schul- D-H 1973
Lead	Blue mussel (Mytilus edulis)	Invert	ŝ	51	Soft mete	00000000	0000000	0000	0.0%/	Schulz-Baides 1972
Lead	Blue mussel (Mytilus edulis)	Invert	n s		Con parts	565711	00751	2 8	0.0261	Phillips 1976
beat	Blue mussel (Monitus edutis)						00561	8	/65.0	Phillips 1976
l ead	Rine mussel (Mutilus adults)		* *	с С	Soli parts	148889	20100	40	502.5	Phillips 1976
		Invert	A S	35	Soft parts	82222	11100	20	555.0	Phillips 1976
Lead	Caudisity (brachycentrus sp.)	Invert	FW	28	WB	300000	60000	32	1875.0	Spehar et al. 1978
	Caddistry (Brachycentrus sp.)	Invert	FW	28	WB	30000	00009	67	895.5	Spehar et al. 1978
Lead	Caddisfly (Brachycentrus sp.)	Invert	FΨ	28	WB	30000	00009	136	441.2	Spehar et al. 1978
Lead	Caddisfly (Brachycentrus sp.)	Invert	FW	28	WB	000009	120000	277	433.2	Spehar et al 1978
Lead	Caddisfly (Brachycentrus sp.)	Invert	FW	28	WB	100000	20000	565	354.0	Spehar et al. 1978
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW		Soft parts	I	ł	ł	536	USEPA 1985e
Lead	Eastern oyster (Crassostrea virginica)	Invert	ΝS	49	Soft parts	I	17000	25	680.0	Pringle et al. 1968
Lead	Eastern oyst er (Crassostrea virginica)	Invert	ΝS	49	Soft parts	I	35000	20	700.0	Pringle ct al. 1968
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	49	Soft parts	I	75000	001	750.0	Princle et al 1968
Lead	Eastern oyster (Crassostrea virginica)	Invert	ΜS	49	Soft parts	I	20000	200	1000.0	Prinele et al 1968
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	70	Soft parts	I	35100	25	1404.0	Shuster and Prinole 1060
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	70	Soft parts	I	57590	50	1151.8	Shuster and Prinole 1969
Lead	Eastern oyster (Crassostrea virginica)	Invert	ΜS	70	Soft parts	!	102850	001	1028.5	
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	70	Soft parts	I	276750	200	1383.8	
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft tissue	6570	657	-	657.0	Zaroveian et al 1970
Lead	Eastern oyster (Crassostrea virginica)	Invert	SW	140	Soft tissue	11420	1142	3.3	346.1	Zamonejan et al 1070
Lead	Hard clam (Mercenaria mercenaria)	Invert	ΜS	56	Soft parts	I	15000	200	175.0	Pringle et al 1068
Lead	Isopod (Asellus meridianus)	Invert	FW	14	WB	2000000	400000	90	0 0008	
Lead	Snail (Lymnaea palustris)	Invert	FW	120	WB	8500	2500		0.0000	
Lead	Snail (Physa integra)	Invert	ΕW	38				- ;	0.0007	
Lead	Snail (Physa integra)	Invert	EW	07 8 C	0 M	100000	20000	3 5	0.628	
	Snail (Physe internet)			07		40000	20000	9/	1194.0	
	Sual (phus integra)	Invert	×	28	WB	50000	100000	136	735.3	Spehar et al. 1978
	Suan ("mysa integra")	Invert	FW	28	WB	500000	100000	277	361.0	Spehar et al. 1978

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November 5, 1999

Critical Review of the Use of Bioaccumulation Potential for Ilazard Classification of Metals and Metal Compounds

Steries Type	Species clam (Mya arenaria) clam (Mya arenaria) clam (Mya arenaria) Pteronarcys dorsata) Pteronarcys dorsata) Pteronarcys dorsata) Pteronarcys dorsata) Pteronarcys dorsata) sel (Dreissena polymorpha) forella solina)			days) 70	Tissue	(µg/kg-dry)	(µg/kg-wet)	(J/gr()	BCF 1120.0	Reference
Solit shell (alm ofly arceuric) Device ($3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$	clam Wya arenaria) clam Wya arenaria) clam Wya arenaria) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella sipnica) forella salina)	Invert Invert Invert Invert Invert Invert Invert Invert Mgae Algae	SW SW FW	70				Ĩ	1120.0	
Solvehal (alm) ($q_0 = revarcis)$ Iner SW q_0 z_{23}	clam Wiya arenaria) clam Wiya arenaria) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) reinetla japonica)	Invert Invert Invert Invert Invert Invert Invert Algae Algae	SW SW FW	40	SOIT Dates	ł	112000	8		Prinele et al 1968
Self efficient for accuracia Invest SW SAI parts $$ 2000 200 1370 2 Seneily <i>Prevenucys derstani</i> Invest FW 28 WB 30000 200 21 1975 53 Steneily <i>Prevenucys derstani</i> Invest FW 28 WB 30000 2000 20 1300 72 23 </td <td>clam (Mya arenaria) Veronarcys dorsata) Veronarcys dorsata) Veronarcys dorsata) Veronarcys dorsata) Sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella japonica) (orella salma)</td> <td>Invert Invert Invert Invert Invert Invert Algae Algae</td> <td>SW FW</td> <td>24</td> <td>Soft parts</td> <td>ł</td> <td>235000</td> <td>200</td> <td>1175.0</td> <td>Pringle et al. 1968</td>	clam (Mya arenaria) Veronarcys dorsata) Veronarcys dorsata) Veronarcys dorsata) Veronarcys dorsata) Sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella japonica) (orella salma)	Invert Invert Invert Invert Invert Invert Algae Algae	SW FW	24	Soft parts	ł	235000	200	1175.0	Pringle et al. 1968
Strengly $Pre-noncyst dension Invest FW 28 WB 30000 6000 32 1873 5 Strengly Pre-noncyst dension Invest FW 28 WB 30000 6000 37 733 5 Strengly Pre-noncyst dension Invest FW 28 WB 30000 6000 37 733 5 Strengly Pre-noncyst dension Invest FW 28 WB 30000 6000 37 733 736 5 736 5 780 5 780 5 780 5 780 5 780 5 780 5 780 5 780 5 780 5 780 5 780 $	Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Sel Wreissena polymorpha) Sel Wreissena polymorpha) Sel Wreissena polymorpha) Sel Wreissena polymorpha) erionella japonica) erionella salma)	Invert Invert Invert Invert Invert Algae Algae	ЕW	84	Soft parts	I	260000	200	1300.0	Pringle et al. 1968
Struchly (Percontroy dorsate) Inert FW 28 WB 500000 677 4925 5 Struchly (Percontroy dorsate) Inert FW 28 WB 500000 100000 573 735 5 Struchly (Percontroy dorsate) Invert FW 28 WB 500000 200000 273 735 5 735 5 735 5 735 5 735 5 735 5 735 5 735 5 736 5 736 5 736 5 736 5 736 5 736 5 730 5 730 5 730 5 735 5 735 5 735 5 735 5 735 5 735 5 732 5 735 5 735 5 7 730 5 735 5 7 735 5 7 735 5 5 7 7 7	Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) erionella japonica) erionella salina)	Invert Invert Invert Invert Invert Algae Algae	:	28	WB	30000	60000	32	1875.0	Spehar et al. 1978
Stunctly (Perconarcy densitie) Invest FW 28 WB 500000 100000 116 733.3 53 Sturthy (Perconarcy densitie) Invest FW 28 WB 1000000 266 77 720.6 Sturthy (Perconarcy densitie) Invest FW 28 Still pairs 900 90 0.5 730.0 57 732.0 5 Zehn muscel (Deristore polymorphic) Invest FW 70 56 73 732.0 5 731.0 5 731.0 5 731.0 5 731.0 5 731.0 5 731.0 5 732.0 5 732.0 5 732.0 5 731.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 5 732.0 <td>Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) erionella japonica) lamydomonas sp.) lorella salma)</td> <td>Invert Invert Invert Invert Invert Algae Algae</td> <td>FW</td> <td>28</td> <td>WB</td> <td>50000</td> <td>100000</td> <td>67</td> <td>1492.5</td> <td>Spehar et al. 1978</td>	Peronarcys dorsata) Peronarcys dorsata) Peronarcys dorsata) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) erionella japonica) lamydomonas sp.) lorella salma)	Invert Invert Invert Invert Invert Algae Algae	FW	28	WB	50000	100000	67	1492.5	Spehar et al. 1978
Store (I) Processor dotation) Intert FW 28 WB 2000000 277 723.0 5 730.0 577 732.0 733.0	Peronarcys dorsata) Peronarcys dorsata) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) erionella japonica) lamydomonas sp.) lorella salina)	Invert Invert Invert Invert Algae Algae	FW	28	WB	50000	10000	136	735.3	Spehar et al. 1978
Conclust for the rest in there in thereres in the rest in the rest in the rest in the rest	Peronarcys dorsata) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) erionella japonica) lamydomonas sp.) lorella salina)	Invert Invert Invert Invert Algae Algae	FW	28	WB	100000	20000	277	722.0	Spehar et al. 1978
Zebra musei ($Dreisena polymorpha) Inver FW 70 Sch parts 900 90 0.5 1800 Zebra musei (Dreisena polymorpha) Inver FW 70 Sch parts 10000 1000 4 20 Zebra musei (Dreisena polymorpha) Inver FW 70 Sch parts 11000 100 4 20 111 K Zebra musei (Dreisena polymorpha) Inver FW 70 Sch parts 10000 1000 4 120 8 111 1 K 2 Sch parts 10000 1000 4 120 1 $	sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) sel Ureissena polymorpha) erionella japonica) lamydomonas sp.)	Invert Invert Invert Algae Algae	FW	28	WB	200000	40000	565	708.0	Spehar et al. 1978
Zebra musc (Drésteran polymorpha) Invert FW 70 Seft parts 1000 1000 4 2300 8 Zebra musc (Drésteran polymorpha) Invert FW 70 Seft parts 10000 1000 4 2300 Zebra musc (Drésteran polymorpha) Invert FW 70 Seft parts 10000 1000 4 2300 Zebra musc (Drésteran polymorpha) Invert FW 70 Seft parts 10000 1100 10 11 10 Zebra musc (Drésteran polymorpha) Invert FW 70 Seft parts 10000 1100 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 11 10 10 11 10 11 10 11 10 11 10 11 10 10 10 10 10 10 <td>sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) erionella japonica) lamydomonas sp.) lorella salina)</td> <td>Invert Invert Invert Algae Algae</td> <td>FW</td> <td>70</td> <td>Soft parts</td> <td>006</td> <td>90</td> <td>0.5</td> <td>180.0</td> <td>Kraak et al. 1994</td>	sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) sel Wreissena polymorpha) erionella japonica) lamydomonas sp.) lorella salina)	Invert Invert Invert Algae Algae	FW	70	Soft parts	006	90	0.5	180.0	Kraak et al. 1994
Zeha musel (<i>Dreitsenta polymorpha</i>) Invert FW 70 Soft parts 1100 110 100 100 110 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 <td>sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella japonica) tamydomonas sp.) forella salina)</td> <td>Invert Invert Algac Algae</td> <td>FW</td> <td>70</td> <td>Soft parts</td> <td>00001</td> <td>1000</td> <td>4</td> <td>250.0</td> <td>Kraak et al. 1994</td>	sel (Dreissena polymorpha) sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella japonica) tamydomonas sp.) forella salina)	Invert Invert Algac Algae	FW	70	Soft parts	00001	1000	4	250.0	Kraak et al. 1994
Zehra mussel (<i>Dreistera polymorpha</i>) Invet FW 70 Soft parts 4000 400 56 111.1 Zehra mussel (<i>Dreistera polymorpha</i>) Invet FW 70 Soft parts 4000 400 56 111.1 Agee (<i>Alteriodial jopicia</i>) Neet FW 70 Soft parts 5000 500 5	sel (Dreissena polymorpha) sel (Dreissena polymorpha) erionella japonica) tamydomonas sp.) lorella salina)	Invert Invert Algae Algae	FW	70	Soft parts	11000	1100	10	110.0	Kraak et al. 1994
Zeha musel (D'enterand projention) Inset FW 70 Soft pairs 13000 1300 85 152.9 N Alge (Chinordenious T_p) Algere SW 25 Cells 54000 5400 5000 111 5 Alge (Chinordenious T_p) Algere SW 25 Cells 54000 6400 5000 110 5 Alge (Chinordenious T_p) Algere SW 25 Cells 31000 3100 3000 5000 11 5 Alge (Universitie primeters) Algere SW 25 Cells 31000 3100 3100 3100 3100 310 5000 11 5 Algere (Herrischnic traiters) Algere SW 25 Cells 31000 3100 310 310 3000 310	sel (Dreissena polymorpha) erionella japonica) tamydomonas sp.) torella solina)	Invert Algae Algae	FW	70	Soft parts	40000	4000	36	1.11.1	Kraak et al. 1994
Age (Asteriondle jepotica) Age (Startondle jepotica) Age (Startondle jepotica) Mge (Control anima) S400 5400 5400 5400 5000 501 F Age (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) S000 500 011 F Age (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) S000 011 F Alge (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) Age (Chinchedia anima) S000 01 F Alge (Finition brunscens) Alge (Finition brunscens) Alge (Finition brunscens) Alge (Finition brunscens) S000 01 F Alge (Finition brunscens) Alge S(Finition brunscens) Alge S(Finition brunscens) Alge S(Finition brunscens) S000 S000 01 F Alge (Chinchedia anita) Alge S(Finition brunscens) Alge S(Finition brunscens) S000 S000 <t< td=""><td>erionella japonica) tamydomonas sp.) torella solina)</td><td>Algac Algae Algae</td><td>FW</td><td>70</td><td>Soft parts</td><td>130000</td><td>13000</td><td>85</td><td>152.9</td><td>Kraak et al. 1994</td></t<>	erionella japonica) tamydomonas sp.) torella solina)	Algac Algae Algae	FW	70	Soft parts	130000	13000	85	152.9	Kraak et al. 1994
Alge (Chlomydomonar sp.) Alge SV 25 Cells 6800 680 500 0.1 F Alge (Chlomydomonar sp.) Alge (Chlomydomonar sp.) Alge (Chloreda) Alge (Chloreda) 500 500 0.1 F Alge (Chloreda) Alge (Chloreda) Alge (Chloreda) Alge (Chloreda) 500 500 0.1 F Alge (Chloreda) Alge (Chloreda) Alge SV 25 Cells 3100 3100 500 0.1 F Alge (Chloreda) Alge (Chloreda) Alge SV 25 Cells 3100 3100 500 0.1 F Alge (Merconstric longillis) Alge SV 25 Cells 3000 500 0.1 F Alge (Merconstric longillis) Alge SV 25 Cells 3000 500 0.1 F Alge (Merconstric longillis) Alge SV 25 Cells 3000 500 0.1 F Alge (Merconstric longillis) Alge SV 25 Cells 3000 500 <td>'amydomonas sp.) Iorella salina)</td> <td>Algae Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>54000</td> <td>5400</td> <td>5000</td> <td></td> <td>Rilev and Roth 1971</td>	'amydomonas sp.) Iorella salina)	Algae Algae	SW	25	Cells	54000	5400	5000		Rilev and Roth 1971
Age Chlorella alina Age SW 25 Cells 1130 500 1.0 R Age Ubmiddla revidecat) Age SW 25 Cells 1130 500 0.1 F Age Ubmiddla revidecat) Age SW 25 Cells 1130 500 0.1 F Age Ufenitelmis branescens) Age SW 25 Cells 1130 500 0.1 F Age Ufenitelmis branescens) Age SW 25 Cells 1130 300 500 0.1 F Alge Use SW 25 Cells 1300 300 500 0.1 F Alge Wonchrysti lufteri) Alge SW 25 Cells 1300 300 00 0.1 F F Alge Wonchrysti lufteri) Alge SW 25 Cells 7300 700 700 700 700 700	lorella salina)	Algae	SW	25	Cells	6800	680	5000	0.1	Rilev and Roth 1971
Ager Obrainella prinolecca) Ager SW 25 Cells 11500 1150 5000 0.1 5 Ager Obrainella prinolecca) Ager SW 25 Cells 3800 380 5000 0.1 5 Ager Obrainella prinoleca Ager SW 25 Cells 3800 380 5000 0.1 5 Ager Offensemis tracers Ager SW 25 Cells 14500 1450 5000 0.1 5 Ager Offensemis tracers Ager SW 25 Cells 14500 1450 5000 0.1 5 Ager Offensemis tracers Ager SW 25 Cells 2000 201 5 5 Ager Offenser SW 25 Cells 77000 7900 5000 0.1 7 Ager Offenser SW 25 Cells 77000 7900 700 7 4 4 Ager Offenser SW 25 Cells 77000 7000 7 4		,	SW	25	Cells	48000	4800	5000	1.0	Rilev and Roth 1971
Age (Duratical teriolecar) Alge SW 25 Cells 380 380 500 0.1 F Age (Herrischnis brunzeens) Alge SW 25 Cells 3300 3300 500 0.1 F Age (Herrischnis brunzeens) Alge SW 25 Cells 3300 500 0.1 F Age (Herrischnis irrecens) Alge SW 25 Cells 3300 500 0.1 F Age (Micronoma squamua) Alge SW 25 Cells 29000 500 0.1 F Age (Micronoma squamua) Alge SW 25 Cells 29000 500 0.1 F Age (Micronoma squamua) Alge SW 25 Cells 7300 7000 500 0.1 F Age (Micronoma squamua) Alge SW 25 Cells 7300 700 500 0.1 F Age (Micronoma squamua) Alge SW 25 Cells 5000 500 0.1 F Age (Micronoma squamua)	naliella primolecta)	Algae	SW	25	Cells	11500	1150	5000	0.2	Rilev and Roth 1971
Algae (Heniselmis brurexcens) Algae (Heniselmis brurexcens) Algae (Heniselmis brurexcens) Algae (Heniselmis brurexcens) Algae (Heniselmis inverscens) Algae (Heniselmis) Algae (H	naliella tertiolecta)	Algae	SW	25	Cells	3800	380	5000	0.1	Rilev and Roth 1971
Algae (Henriselmis virsecres.) Algae SW 25 Cells 600 600 500 01 F Algae (Henromastix longifilis.) Algae SW 25 Cells 14500 1450 900 0.1 F Algae (Monochrysis lunker.) Algae SW 25 Cells 14500 1450 900 0.1 F F Algae (Viscontors squamata) Algae SW 25 Cells 29000 2900 0.0 6.6 6.0 <td>niselmis brunescens)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>33000</td> <td>3300</td> <td>5000</td> <td>0.7</td> <td>Rilev and Roth 1971</td>	niselmis brunescens)	Algae	SW	25	Cells	33000	3300	5000	0.7	Rilev and Roth 1971
Algae (Heromatric long)(ilits) Algae SW 25 Cells 14500 1450 500 0.3 F Algae (Micronnars quantata) Algae SW 25 Cells 29000 2900 5000 0.4 F Algae (Micronnars quantata) Algae SW 25 Cells 29000 2900 5000 0.4 F Algae (Micronnuts) Algae SW 25 Cells 20000 2000 0.6 F Algae (Pseudopedinella pyr/formis) Algae SW 25 Cells 30000 3000 0.6 F Algae (Fseudopedinella pyr/formis) Algae SW 25 Cells 30000 3000 0.6 F Algae (Fseudopedinella pyr/formis) Algae SW 25 Cells 30000 3000 0.6 F Algae (Fseudopedinella pyr/formis) Algae SW 25 Cells 30000 3000 0.6 F Algae (Fseudopedinella pyr/formis) Alga	niselmis virescens)	Algae	SW	25	Cells	0009	600	5000	0.1	Riley and Roth 1971
Algae Wicrononas squamata) Algae SW 25 Cells 2900 2900 500 0.6 F Algae Unoncohysis lutheri) Algae SW 25 Cells 2900 500 14 F Algae Unoncohysis lutheri) Algae SW 25 Cells 7300 500 14 F Algae Unoncons squamata) Algae SW 25 Cells 7300 500 15 F Algae Unocorea barella priformis) Algae SW 25 Cells 3000 500 15 F Algae Viscorcorus barellaris) Algae SW 25 Cells 4600 500 0.6 15 F Algae Viscorcorus barellaris) Algae SW 25 Cells 4600 500 0.1 F F 5 Cells 4600 500 12 F F F F F F F F F F F F F <t< td=""><td>eromastix longifillis)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>14500</td><td>1450</td><td>5000</td><td>0.3</td><td>Riley and Roth 1971</td></t<>	eromastix longifillis)	Algae	SW	25	Cells	14500	1450	5000	0.3	Riley and Roth 1971
Algae (Monochrysis lurheri) Algae SW 25 Cclls 6900 6900 5000 1.4 F Algae (VisiAdorycus lureus) Algae SW 25 Cclls 2000 2000 5000 0.4 F Algae (VisiAdorycus lureus) Algae SW 25 Cclls 3000 7300 5000 0.4 F Algae (VisiAdorycus lureus) Algae SW 25 Cclls 3000 7000 5000 0.4 F Algae (Frischorscus lureus) Algae SW 25 Cclls 4600 460 900 10 1 1 Algae (Frischorscus lureus) Algae SW 25 Cclls 4600 460 900 1.2 1 Algae (Frischorscus lureus) Algae SW 32 Cells 4600 460 900 1.2 1 Algae (Frischorscus lureus) Algae SW 32 Cells 4600 460 145.0 1 Algae (Frischorscus lureus) Fish SW <td< td=""><td>cromonas squamata)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>29000</td><td>2900</td><td>5000</td><td>0.6</td><td>Riley and Roth 1971</td></td<>	cromonas squamata)	Algae	SW	25	Cells	29000	2900	5000	0.6	Riley and Roth 1971
Algae (<i>Olisthodiscus luteus</i>) Algae SW 25 Cells 73000 2000 5000 0.4 F Algae (<i>Phaeodacylum ricornuum</i>) Algae SW 25 Cells 73000 3000 5000 0.4 F Algae (<i>Phaeodacylum ricornuum</i>) Algae SW 25 Cells 73000 3000 5000 0.6 F Algae (<i>Sinchococcub bacillaris</i>) Algae SW 25 Cells 3000 5000 0.1 F Algae (<i>Sinchococcub bacillaris</i>) Algae SW 25 Cells 3000 5000 0.1 F Algae (<i>Innaulia anguila</i>) Fish SW 32 Digestive tract - 18000 100 1800 102 123 12400 Eel (<i>Anguila anguila</i>) Fish SW 32 Cill filaments - 18000 100 185.0 124.0 124.0 124.0 124.0 124.0 124.0 124.0 124.0 124.0 124.0	nochrysis lutheri)	Algae	SW	25	Cells	69000	6900	5000	1.4	Riley and Roth 1971
Algae (Phaeodacrylum tricornutum) Algae SW 25 Cells 73000 7300 5000 15 F Algae (Pseudopedinella pyr/jormis) Algae SW 25 Cells 30000 3000 5000 0.6 F Algae (Stichococcus bacillaris) Algae SW 25 Cells 30000 5000 0.1 F Algae (Stichococcus bacillaris) Algae SW 25 Cells 5000 600 1.2 F Algae (Terrasemis terrahelt) Algae SW 25 Cells 65000 600 1.2 F Algae (Terrasemis terrahelt) Algae SW 32 Cells 65000 600 1.2 F Algae (Terrasemis terrahelt) Algae SW 32 Cells 65000 600 1.2 F Algae SW SW 32 Cill filaments	sthodiscus luteus)	Algae	SW	25	Cells	20000	2000	5000	0.4	Riley and Roth 1971
Algae <i>Pseudopedinella pyriformis</i>) Algae SW 25 Cells 3000 3000 500 0.6 F Algae <i>Stichococcus bacillaris</i>) Algae SW 25 Cells 4600 460 500 0.1 F Algae <i>Stichococcus bacillaris</i>) Algae SW 25 Cells 4600 460 500 0.1 F Algae <i>Stichococcus bacillaris</i>) Algae SW 25 Cells 62000 6200 5000 1.2 T Eel <i>Unguila anguila</i>) Fish SW 32 Digestive tract	ieodactylum tricornutum)	Algae	SW	25	Cells	, 73000	7300	5000	1.5	Riley and Roth 1971
Algae Stichococcus bacillaris) Algae SW 25 Cells 4600 460 500 0.1 F Algae (Tetraseinis terrathet) Algae SW 25 Cells 62000 6200 5000 1.2 7 Eel (Arguilla anguilla) Ei thish SW 32 Bile - 18000 100 1850 12 7 Eel (Arguilla anguilla) Fish SW 32 Digestive tract - 14500 100 145.0 100 145.0 1 Eel (Arguilla anguilla) Fish SW 32 Digestive tract - 14500 100 145.0 1 1 Eel (Arguilla anguilla) Fish SW 32 Uilver - 14500 100 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 157.0 1 1 1 1 </td <td>udopedinella pyriformis)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>30000</td> <td>3000</td> <td>5000</td> <td>0.6</td> <td>Riley and Roth 1971</td>	udopedinella pyriformis)	Algae	SW	25	Cells	30000	3000	5000	0.6	Riley and Roth 1971
Algae (Tetraseinis terrathet) Algae SW 25 Cells 6200 6200 500 1.2 7 Eel (Arguilla anguilla) Fish SW 32 Bile 18000 100 180.0 145.0 100 180.0 145.0 100 180.0 145.0 100 145.0 145.0 100 145.0 100 145.0 145.0 100 145.0 100 145.0 100 145.0 <	hococcus bacillaris)	Algae	SW	25	Cells	4600	460	5000	0.1	Riley and Roth 1971
Ecl (Anguilla anguilla) Fish SW 32 Bile 18000 100 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 185.0 180.0 185.0	raseimis tetrathele)	Algae	SW	25	Cells	62000	6200	5000	1.2	Riley and Roth 1971
Eel (Anguilla anguilla) Fish SW 32 Digestive tract 14500 100 145.	lla anguilla)	Fish	SW	32	Bile	1	18000	001	180.0	Noel-Lambot and Bouquegneau 1977
Ecl (Anguilla anguila) Fish SW 32 Gill filaments 66900 100 669.0 1 Ecl (Anguilla anguilla) Fish SW 32 Kidneys 115700 100 669.0 157.0 100.0 157.0 100.0 157.0 157.0 157.0 157.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157.0 100.0 157	lla anguilla)	Fish	SW	32	Digestive tract	I	14500	100	145.0	Nocl-Lambot and Bouquegneau 1977
Eel (Anguilla anguilla) Fish SW 32 Kidneys - 115700 100 1157.0 157.0 1057.0 1157.0 1157.0 100 1157.0 1157.0 100 1157.0 1100.0 1157.0 1100.0 1157.0 1100.0 1100.0 1157.0 1100.0 1100.0 1100.0 1100.0 1157.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 1100.0 <t< td=""><td>lla anguilla)</td><td>Fish</td><td>SW</td><td>32</td><td>Gill filaments</td><td>ł</td><td>66900</td><td>001</td><td>669.0</td><td>Noel-Lambot and Bouquegneau 1977</td></t<>	lla anguilla)	Fish	SW	32	Gill filaments	ł	66900	001	669.0	Noel-Lambot and Bouquegneau 1977
Ecl (Anguilla anguilla) Fish SW 32 Liver - 48500 100 485.0 155.0 155.0	lla anguilla)	Fish	SW	32	Kidneys	I	115700	100	1157.0	Noel-Lambot and Bouquegneau 1977
Ect (Anguilla anguilla) Fish SW 32 Muscles 13400 100 134.0 1 Ect (Anguilla anguilla) Fish SW 32 Skin 18800 100 188.0 1 Ect (Anguilla anguilla) Fish SW 32 Splcen 18000 100 188.0 1 100.0 1 88.0 1	lla anguilla)	Fish	SW	32	Liver	1	48500	100	485.0	Noel-Lambot and Bouquegneau 1977
Ecl (Anguilla anguilla) Fish SW 32 Skin - 18800 100 188.0 1 Ecl (Anguilla anguilla) Fish SW 32 Spleen - 110000 100 1100.0 1 Ecl (Anguilla anguilla) Fish SW 32 Spleen - 15300 100 153.0 1 Ecl (Anguilla anguilla) Fish FW 60 WB - 15300 100 153.0 1 Fathcad minnow <i>Pimephales promelas</i>) Fish FW 60 WB - 72000 64 1125.0 1 Decideration to (Occorhynchus mykiss) Fish FW 90 Brain - 72000 64 1125.0 1	lla anguilla)	Fish	SW	32	Muscles	ł	13400	001	134.0	Noel-Lambot and Bouquegneau 1977
Eel (Anguilla anguilla) Fish SW 32 Spleen 110000 100 1100.0 1 Eel (Anguilla anguilla) Fish SW 32 WB 15300 100 153.0 1230.0 64 1125.0 1 1125.0 1 1125.0 1 1125.0 1 1125.0 1 1125.0 1 100.0 100.0 100.0 100.0 100.0 100.0 1125.0 1 100.0 100.0 1125.0	lla anguilla)	Fish	SW	32	Skin	1	18800	1 00	188.0	Noel-Lambot and Bouquegneau 1977
Eel (Anguilla anguilla) Fish SW 32 WB - 15300 100 153.0 163.0 153.0 153.0 163.0 153.0 170.0 64 1125.0 1125.0 100.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 1125.0 100.0 100.0 1125.0 100.0 100.0 1125.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 1125.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 </td <td>lla anguilla)</td> <td>Fish</td> <td>SW</td> <td>32</td> <td>Spleen</td> <td>ł</td> <td>110000</td> <td>001</td> <td>1100.0</td> <td>Noel-Lambot and Bouquegneau 1977</td>	lla anguilla)	Fish	SW	32	Spleen	ł	110000	001	1100.0	Noel-Lambot and Bouquegneau 1977
Fathcad minnow (Pimephales prometas) Fish FW 60 WB 800 0.31 2380.6 Rainbow trout (Oncorhynchus mykiss) Fish FW 90 Brain 72000 64 1125.0 Database records of the matrix Fish FW 90 Brain 72000 64 1125.0	lla anguilla)	Fish	SW	32	WB	I	15300	001	153.0	Noel-Lambot and Bouquegneau 1977
Rainbow trout (Oncorthynchus mykiss) Fish FW 90 Brain 72000 64 1125.0 1 Brainbow trout (Oncortin-true mitter) r.t. r.t. co	innow (Pimephales promelas)	Fish	FW	60	WB	-	800	0.31	2580.6	Snarski and Olson 1982
	rout (Oncorhynchus mykiss)	Fish	FW	06	Brain	ł	72000	29	1125.0	Niimi and Kissoon 1994
Fish FW 90 Gill - 76000 64 1187.5	rout (Oncorhynchus mytuss)	Fish	FW	60	Gill	I	76000	2	1187.5	Niimi and Kissoon 1994
		Algac (Dunatiella primolecta) Algae (Dunatiella tertiolecta) Algae (Hemiselmis brunescens) Algae (Hemiselmis virescens) Algae (Heteromastix longifilis) Algae (Monochrysis lutheri) Algae (Monochrysis lutheri) Algae (Monochrysis lutheri) Algae (Preudopedinella pyriformis) Algae (Preudopedinella pyriformis) Algae (Preudopedinella pyriformis) Algae (Feraseimis terrathele) Eel (Anguilla anguilla) Eel (Anguilla anguilla) Eil (Anguilla anguilla)		Algae Algae Algae Algae Algae Algae Algae Fish Fish Fish Fish Fish Fish Fish	Algae SW Algae SW Alg	Algae SW 25 Algae SW 25 Fish SW 32 Fish SW 32 Fish SW 32 Fish SW 32 Fish SW 32 Fish FW 60 Fish FW 90 Fish FW 90	Algae SW 25 Cells Algae SW 25 Cells Fish SW 32 Digestive tract Fish SW 32 Digestive tract Fish SW 32 Cells Fish FW 90 Brients Fish FW 90 Brain Fish FW 90 Brain	Algae SW 25 Cells 11500 Algae SW 25 Cells 33000 Algae SW 25 Cells 3100 Algae SW 25 Cells 5000 Algae SW 25 Cells 2000 Algae SW 25 Cells 3000 Algae SW 25 Cells 4600 Algae SW 25 Cells 3000 Algae SW 25 Cells 4600 Fish SW 32 Digestive tract - Fish SW 32 Digestive tract - Fish SW 32 NB - - Fish SW 32 Digestive tract <	Alger SW 25 Cells 11500 1150 Algare SW 25 Cells 33000 3300 3300 Algare SW 25 Cells 5000 500 500 Algare SW 25 Cells 1450 1450 1450 Algare SW 25 Cells 5000 2900 290 Algare SW 25 Cells 3000 300 300 Fish SW 32 Cells 3000 300 300 Fish SW 32 Cells 460 460 460 Fi	$ \begin{array}{llllllllllllllllllllllllllllllllllll$

Critical Review of the Use of Bioaccumulation Potential for Ilazard Classification of Metals and Metal Compounds

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		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Iype	lype	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(J18/L)	BCF	Reference
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	8	Kidney	I	395000	64	6171.9	Niimi and Kissoon 1994
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	8	Liver	I	233000	2	3640.6	Niimi and Kissoon 1994
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	90	Muscle	I	2900	25	45.3	Niimi and Kissoon 1994
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW		Muscle, bone, skin	1700	340	560	0.6	Wilson 1983
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	-	Muscle, bone, skin	1200	240	75	3.2	Wilson 1983
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	-	Muscle, bone, skin	1700	340	0001	0.3	Wilson 1983
Mercury (inorganic)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	90	Spleen	1	117000	5	1828.1	Niimi and Kissoon 1994
Mercury (inorganic)	Amphipod (<i>Ityalella azteca</i>)	Invert	FW	70	WB	420	84	0.05	1680.0	Borgmann et al. 1993
Mercury (inorganic)	Amphipod (Hyalella azteca)	Invert	FΨ	02	WB	25000	5000	0.62	8064.5	Borgmann et al. 1993
Mercury (inorganic)	Amphipod (Hyalella azteca)	Invert	FW	70	WB	56000	11200	1.12	10000.0	Borgmann et al. 1993
Mercury (inorganic)	Eastern oyster (Crassostrea virginica)	Invert	SW		Soft parts	I	ł	I	10,000	USEPA 1985f
Mercury (inorganic)	Eastern oyster (Crassostrea virginica)	Invert	SW	99	Soft parts	ł	16000	01	1,600	Cunningham and Tripp 1973
Mercury (inorganic)	Eastern oyster (Crassostrea virginica)	Invert	SW	60	Soft parts	I	100000	100	1,000	Cunningham and Tripp 1973
Mercury (inorganic)	Water flea (Daphnia magna)	Invert	FW	21	WB	1260	126	<0.0>	<12600	Bicsinger et al. 1982
Mercury (inorganic)	Water flea (Daphnia magna)	Invert	FW	21	WB	8590	859	0.36	2386	Biesinger et al. 1982
Mercury (inorganic)	Water flea (Daphnia magna)	Invert	FW	21	WB	15260	1526	0.72	2119	Biesinger et al. 1982
Nickel	Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	7100	710	80	68	Riley and Roth 1971
Nickel	Algae (Chlorella salina)	Algae	ΜS	25	Cells	3100	310	80	39	Riley and Roth 1971
Nickel	Algae (Dunaliella primolecta)	Algae	SW	25	Cells	6400	640	80	80	Riley and Roth 1971
Nickel	Algae (Dunaliella tertiolecta)	Algae	SW	25	Cells	4300	430	•0	54	Riley and Roth 1971
Nickel	Algae (Hemiselmis brunescens)	Algae	SW	25	Cells	3300	330	90	41	Riley and Roth 1971
Nickel	Algae (Hemiselmis virescens)	Algae	SW	25	Cells	2800	280	æ	35	Riley and Roth 1971
Nickel	Algae (Heteromastix longifillis)	Algae	SW	25	Cells	10300	1030	80	129	Riley and Roth 1971
Nickel	Algae (Micromonas squamata)	Algae	SW	25	Cells	6700	670	œ	84	Rilcy and Roth 1971
Nickel	Algae (Monochrysis lutheri)	Algae	ΝS	25	Cells	7500	750	e 0	94	Ril e y and Roth 1971
Nickel	Algae (Olisthodiscus luteus)	Algae	SW	25	Cells	2700	270	80	34	Riley and Roth 1971
Nickel	Algae (Phaeodactylum tricornutum)	Algae	ΝS	25	Cells	6200	620	80	78	Riley and Roth 1971
Nickel	Algae (Pseudopedinella pyriformis)	Algae	ΜS	25	Cells	4900	490	•0	19	Riley and Roth 1971
Nicket	Algae (Scenedesmus acuminata)	Algae	FW	9	WB	I	I	1000	9.3	USEPA 1986
Nickel	Algae (Stichococcus bacillaris)	Algae	ΜS	25	Cells	2900	290	œ	36	Riley and Roth 1971
Nickel	Algæ (Tetraseimis tetrathele)	Algae	ΝS	25	Cells	5600	560	œ	70	Riley and Roth 1971
Nickel	Brown macroalgae Uscophylium nodosum)	Algae	SW	Field	WB	2750	550	1.2	458.3	USEPA 1986
Nickel	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	11130	2226	21	106	Lind et al. Manuscript
Nickel	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	17600	3520	44.4	61	Lind et al. Manuscript
Nickel	Fathead minnow (Pimephales promelas)	Fish	FW	30	WB	25480	5096	108.9	47	Lind et al. Manuscript
Nickel	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Kidney	ł	4023	1000	4.0	Calamari et al. 1982
Nickel	Rainbow trout (Oncorhynchus mykiss)	Fish	FΨ	180	Liver	ł	2923	1000	2.9	Calamari et al. 1982
Nickel	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	180	Muscle	i	816	1000	0.8	Calamari et al. 1982
Nickel	Bivalve (Cerastoderma edule)	Invert	SW	26	WB	59600	5960	0.1	59600.0	Wilson 1983
Nickel	Bivalve (Cerastoderma edule)	Invert	SW	26	WB	133700	13370	-	13370.0	Wilson 1983

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

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		Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-dry)	(µg/kg-wet)	(hg/L)	BCF	Reference
Nickel	Bivalve (Cerastoderma edule)	Invert	SW	26	WB	319800	31980	01	3198.0	Wilson 1983
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	0009	600	4.4	136.4	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	ΜS	84	Soft parts	6000	600	4,4	136.4	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	ΜS	84	Soft parts	10000	1000	4.4	227.3	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	ΜS	84	Soft parts	11000	0011	4.4	250.0	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	15000	1500	4.4	340.9	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	14000	1400	01	140.0	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	15000	1500	10	150.0	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	ΝS	84	Soft parts	15000	1500	10	150.0	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	16000	1600	10	160.0	Zaroogian and Johnson 1984
Nickel	Blue mussel (Mytilus edulis)	Invert	SW	84	Soft parts	22000	2200	10	220.0	Zaroogian and Johnson 1984
Nickel	Cladoceran (Daphnia magna)	Invert	FW		WB	I	I	I	001	USEPA 1986
Nickel	Cladoceran <i>Waphnia magna</i>)	Invert	FW	3.75	WB	l	0096	50	192.0	Hall 1982
Nickel	Cladoceran (Daphnia magna)	Invert	FW	3.75	WB	1	92250	750	123.0	Hall 1982
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	7000	700	4.2	166.7	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	8000	800	4.2	190.5	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	SW	84	Soft parts	10000	1000	4.2	238.1	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΝS	84	Soft parts	11000	1100	4.2	261.9	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	SW	84	Soft parts	14000	1400	4.2	333.3	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	11000	1100	9.9	1111	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	13000	1300	9.9	131.3	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	15000	1500	9.9	151.5	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	SW	84	Soft parts	16000	1600	9.9	161.6	Zaroogian and Johnson 1984
Nickel	Eastern oyster (Crassostrea virginica)	Invert	ΜS	84	Soft parts	18000	1800	9.9	181.8	Zaroogian and Johnson 1984
Nickel	Rockweed (Fucus vesiculosis)	Plant	SW	Field	WB	4050	810	1.2	675.0	USEPA 1986
Sclenium (6:1 VI:IV)	Bluegill (Lepomis macrochirus)	Fish	SΨ	60	WB	1000	200	20	10.0	Cleveland et al. 1993
Selenium (6:1 VI:IV)	Bluegill (Lepomis macrochirus)	Fish	SW	60	WB	2600	520	160	3.3	Cleveland et al. 1993
Selenium (6:1 VI:IV)	Bluegill (Lepomis macrochirus)	Fish	SW	60	WB	3800	760	330	2.3	Cleveland et al. 1993
Selenium (IV)	Bluegill (Lepomis macrochirus)	Fish	FW		WB	I	4500	10	450	USEPA 1987a
Selenium (IV)	Bluegill (Lepomis macrochirus)	Fish	FW		WB	ł	4700	01	470	USEPA 1987a
Selenium (IV)	Bluegill (Lepomis macrochirus)	Fish	FW		WB	I	4300	10	430	USEPA 1987a
Selenium (IV)	Bluegill (Lepomis macrochirus)	Fish	FW		WB	I	4600	01	460	USEPA 1987a
Selenium (IV)	Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	I	2400	120	20	Barrows et al. 1980
Selenium (IV)	Fathead minnow (Pimephales promelas)	Fish	FW	96	WB	I	300	11.57	25.9	Adams 1976
Selenium (IV)	Fathead minnow (Pimephales promelas)	Fish	FW	96	WB	ł	400	24.42	16.4	Adams 1976
Selenium (IV)	Fathead minnow (Pimephales promelas)	Fish	FW	96	WB	ł	600	50.57	11.9	Adams 1976
Selenium (IV)	Largemouth bass Micropterus salmoides)	Fish	FW		WB	I	3100	10	310	USEPA 1987a
Selenium (IV)	Largemouth bass (Micropterus salmoides)	Fish	FW		WB	1	3000	10	300	USEPA 1987a
Selenium (IV)	Largemouth bass (Micropterus salmoides)	Fish	FW		WB	ł	3000	10	300	USEPA 1987a
Selenium (IV)	Largemouth bass (Micropterus salmoides)	Fish	FW		WB	I	2700	10	270	USEPA 1987a

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

November 5, 1999

91 - V

			Organism	Water	Duration		Tissue	Tissue	Water		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Metal/Metalloid	Species	Type	Type	(days)	Tissue	(µg/kg-chy)	(µg/kg-wet)	(J/B/J)	BCF	Reference
un(1)Rations run ($\beta row hynchier and kar)$ EthEw96wrst	Selenium (IV)	Rainbow trout (Oncorhynchus nykiss)	Fish	FW	96	WB	ا	3250	310	10.5	Adams 1976
(1)Rainow treat (Development, model)FishFW108WB1090.332.1aut (1)Rainow treat (Development, model)FishFW55WB73.79.1aut (1)Copped (Megnorighment moregica)FishFW55WB73.79.19.1aut (1)Fahadi attimus (Propulsity)FishFW56WB73.710.77.13aut (1)Fahadi attimus (Propulsity)FishFW56WB73.710.77.13aut (1)Fahadi attimus (Propulsity)FishFW56WB73.710.77.10aut (1)Fahadi attimus (Propulsity)FishFW902344.137.10aut (1)Rainow treat (Development anticit)FishFW902344.137.10aut (1)Rainow treat (Development anticit)FishFW90WB	Seleniun (IV)	Rainbow trout (Oncorhynchus nykiss)	Fish	FW	96	WB	ł	2460	410	6.0	Adams 1976
	Selenium (IV)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	308	WB	ł	160	0.3	533	Hodson et al. 1980
(1)(Selenium (IV)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	308	WB	1	440	47	9.4	Hodson et al. 1980
matrix Time	Selenium (IV)	Copepod (Meganyctiphanes norvegica)	Invert	SW	28	WB	1	1	I	200	Fowler and Benayoun 1976
Image (V) Feature function (<i>Properties</i>) Feature (<i>Procentrols</i>) Feature(<i>Procentrols</i>) Feature (<i>Procentrol</i>	Selenium (VI)	Fathead minnow (Pimephales promelas)	Fish	FW	56	WB	558	145.08	10.7	13.6	Bertram and Brooks 1986
(V)Failups with the formationFishFW56WB002344.355.4out (V)Rainbar total (<i>Orechynchica rybiss</i>)FishFW90WB $$ 90214713673out (V)Rainbar total (<i>Orechynchica rybiss</i>)FishFW90WB $$ 8012.4713713out (V)Rainbar total (<i>Orechynchica rybiss</i>)FishFW90WB $$ 8012.4713out (V)Rainbar total (<i>Orechynchica rybiss</i>)FishFW90WB $$ 8012.4713out (V)Steped lass (<i>Morne scartilis</i>)FishSW60WB $$ 8012.4713out (V)Steped lass (<i>Morne scartilis</i>)FishSW20WB $$ 8012.4713out (V)Steped lass (<i>Morne scartilis</i>)FishSW20WB $$ 8012.4713out (V)Steped lass (<i>Morne scartilis</i>)FishSW20Cells70070012.4713Alge (<i>Chardenica</i>)Alge (<i>Startilis</i>)Alge SWSW23Cells700700700700700Alge (<i>Chardenica</i> SWSW23Cells700700700700700703703Alge (<i>Chardenica</i> Alge (<i>Chardenica</i> Alge SWSW23Cells700700700703703Alge (<i>Chardenica</i> Al	Selenium (VI)	Fathead minnow (Pimephales promelas)	Fish	FW	56	WB	577	150.02	21.5	7.0	Bertram and Brooks 1986
(1)Rainbox true (<i>Checrehous mykis</i>)FishFW90WB-307.87.97.97.9run (1)Rainbox true (<i>Checrehous mykis</i>)FishFW90WB-6002.471.9run (1)Rainbox true (<i>Checrehous mykis</i>)FishFW90WB-6002.471.9run (1)Rainbox true (<i>Checrehous mykis</i>)FishSW60WB-6002.471.9run (1)Rainbox true (<i>Checrehous mykis</i>)FishSW60WB-6002.471.9run (1)Striped base (<i>Morree startilis</i>)FishSW60WB-6002.471.971.9run (1)Striped base (<i>Morree startilis</i>)FishSW60WB-6002.471.971.9run (1)Striped base (<i>Morree startilis</i>)FishSW60WB-6002.171.971.9run (1)Striped base (<i>Morree startilis</i>)FishSW25Cells80008001.371.971.9Alge (<i>Cherohostartilis</i>)AlgeSW25Cells80008000.660.81.2471.9Alge (<i>Cherohostartilis</i>)AlgeSW25Cells80008000.81.7671.971.9Alge (<i>Cherohostartilis</i>)AlgeSW25Cells9009000.871.971.9Alge (<i>Cherohostartilis</i>	Selenium (VI)	Fathead minnow (Pimephales prometus)	Fish	FW	56	WB	906	234	43.5	5.4	Bertram and Brooks 1986
(1)Rainbow tron (<i>Porcubuta miksi</i>)FishFW90WB8012.471.0mar (V)Striped hass (<i>Morres startilis</i>)FishSW60WB602171.2mar (V)Striped hass (<i>Morres startilis</i>)FishSW60WB602171.371.3mar (V)Striped hass (<i>Morres startilis</i>)FishSW60WB602171.371.3mar (V)Striped hass (<i>Morres startilis</i>)FishSW60WB80.011.370.3mar (V)Striped hass (<i>Morres startilis</i>)FishSW20Cells800800.6111.310.3mar (V)Striped hass (<i>Morres startilis</i>)FishSW23Cells800800.6111.310.3Mape (<i>Climationic</i>)Appe (<i>Climationic</i>)AppeSW23Cells800800.6111.3 </td <td>Selenium (VI)</td> <td>Rainbow trout (Oncorhynchus mykiss)</td> <td>Fish</td> <td>FW</td> <td>06</td> <td>WB</td> <td>ļ</td> <td>530</td> <td>7.8</td> <td>61.9</td> <td>Hunn et al. 1987</td>	Selenium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	06	WB	ļ	530	7.8	61.9	Hunn et al. 1987
InterformEasityFW90WB-64021305and (V)Striped base (Merone zacrifis)FishSW60WB-8772123900.68and (V)Striped base (Merone zacrifis)FishSW60WB-8772123900.681and (V)Striped base (Merone zacrifis)FishSW60WB-8772123900.681and (V)Striped base (Merone zacrifis)FishSW25Cells800010001290.681Agree (Marchandar f)Agree (Marchandar f)Agree SW25Cells80008000.6811301Agree (Marchandar f)Agree (Marchandar f)Agree SW25Cells80009000.6811301Agree (Marchandar f)Agree (Marchandar f)Agree SW25Cells9001000.811301Agree (Marchanda f)Agree SW25Cells9009000.8113011Agree (Marchanda f)Agree SW25Cells9009000.811 </td <td>Selenium (VI)</td> <td>Rainbow trout (Oncorhynchus nykiss)</td> <td>Fish</td> <td>FW</td> <td>90</td> <td>WB</td> <td>1</td> <td>880</td> <td>12.4</td> <td>71.0</td> <td>Hunn et al. 1987</td>	Selenium (VI)	Rainbow trout (Oncorhynchus nykiss)	Fish	FW	90	WB	1	880	12.4	71.0	Hunn et al. 1987
mu (VI)Striped hase (<i>Merone statulis</i>)FishSW60WB0900mu (VI)Striped hase (<i>Merone statulis</i>)FishSW60WB800112900.61mu (VI)Striped hase (<i>Merone statulis</i>)FishSW60WB800112900.61mu (VI)Striped hase (<i>Merone statulis</i>)FishSW60WB800112900.61mu (VI)Striped hase (<i>Merone statulis</i>)FishSW25Cells100001000.8111.8Algee (<i>Merone statulis</i>)Algee SW25Cells80008000.8111.912.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells80008000.8111.912.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells1000014100.811.212.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells1000014100.811.212.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells1000014100.812.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells100001000.812.900.61Algee (<i>Merone statulis</i>)Algee SW25Cells100001000.812.9512.95Algee (<i>Merone statulis</i>)Algee SW25Cells100001000.812	Selenium (VI)	Rainbow trout (Oncorhynchus mykiss)	Fish	FW	6	WB	I	640	21	30.5	Hunn et al. 1987
un (V)Stipel base (Morone zaturdits)FishSW60WB-1060.29011.8Cun (V)Stipel base (Morone zaturdits)FishSW60WB-877.212900.66Cun (V)Stipel base (Morone zaturdits)FishSW25C clis80008000.8111.90FAges (Atteriored ta signat)Ages SW25C clis80008000.8111.90FAges (Atteriored ta signat)Ages SW25C clis80008000.8111.90FAges (Atteriored ta signat)Ages SW25C clis90000.0611.90FAges (Atteriored ta signat)Ages SW25C clis90009000.8111.91Ages (Atteriored ta signat)Ages SW25C clis90009000.8111.95Ages (Atteriored ta signat)Ages SW25C clis90009000.8111.75Ages (Atteriored ta signat)Ages SW25C clis91001000.811.75Ages (Atteriored ta signation)Ages SW25C clis91001000.811.75Ages (Atteriored ta signation)Ages SW25C clis910091091017.75Ages (Atteriored ta signation)Ages SW25C clis910091091017.75Ages (Atteriored ta signation)Ages SW25C clis9100910 <t< td=""><td>Selenium (VI)</td><td>Striped bass (Morone saxatilis)</td><td>Fish</td><td>ΒW</td><td>60</td><td>WB</td><td>I</td><td>0</td><td>8</td><td>0</td><td>USEPA 1987a</td></t<>	Selenium (VI)	Striped bass (Morone saxatilis)	Fish	ΒW	60	WB	I	0	8	0	USEPA 1987a
un (V) Striped bass (<i>Morone statulis</i>) Fish SW 60 WB - 8772 1290 0.68 nm (V) Striped bass (<i>Morone statulis</i>) Fish SW 25 Cells 8000 800 0.89 1290 0.68 Alges (<i>Alterritudinity princica</i>) Alges SW 25 Cells 8000 800 0.8 1100 F Alges (<i>Alterritudinity princica</i>) Alges SW 25 Cells 9000 0.8 1120 6 Alges (<i>Alterritudini tyrercersi</i>) Alges SW 25 Cells 9000 980 0.8 1100 F Alges (<i>Alterritudini tyrercersi</i>) Alges SW 25 Cells 3700 100 0.8 755 110 F 755 176 <td>Selenium (VI)</td> <td>Striped bass (Morone saxatilis)</td> <td>Fish</td> <td>ΝS</td> <td>99</td> <td>WB</td> <td>I</td> <td>1060.2</td> <td>8</td> <td>11.8</td> <td>USEPA 1987a</td>	Selenium (VI)	Striped bass (Morone saxatilis)	Fish	ΝS	99	WB	I	1060.2	8	11.8	USEPA 1987a
Interfactor Striped lass (Morone stantis) Fish SW 60 WB - 80.1 1290 0.69 1 Alges (Atternential sponta; Alges SW 25 Cells 0000 0.8 1000 0.8 1000 0.8 1130 5 Alges (Atternential sponta; Alges SW 25 Cells 4000 1000 0.8 1130 5 </td <td>Selenium (VI)</td> <td>Striped bass (Morone saxatilis)</td> <td>Fish</td> <td>SW</td> <td>60</td> <td>WB</td> <td>1</td> <td>877.2</td> <td>1290</td> <td>0.68</td> <td>USEPA 1987a</td>	Selenium (VI)	Striped bass (Morone saxatilis)	Fish	SW	60	WB	1	877.2	1290	0.68	USEPA 1987a
Age (Manydomous sy) Age SW 25 Cells 1000 1000 0.88 1230 F Age (Manydomous sy) Age (Manochynis Maneccus) Age (Manochynis Maneccus) Age (Manochynis Maneccus) Age (Manochynis Manecus) Age (Selenium (V1)	Striped bass (Morone saxatilis)	Fish	SW	60	WB	I	890.1	1290	0.69	USEPA 1987a
Ages Channella prindenonas sp.)Ages SW25Cclis88008800.811005Ages Channella prindeca)Ages SW25Cclis90009000.811055Ages Unualical acrioteca)Ages SW25Cclis90009000.811355Ages Unualical acrioteca)Ages SW25Cclis14100.811355Ages Unualical acrioteca)Ages SW25Cclis14100.811355Ages Unualical acrioteca)Ages SW25Cclis14100.811355Ages UncornauxiAges UncornauxityAges SW25Cclis14100.811355Ages UncornauxiAges UncornauxityAges SW25Cclis10001000.811355Ages UncornauxiAges UncornauxityAges SW25Cclis137000.81735513Ages UncornauxiAges SW25Cclis137000.8173513<	Silver	Algae (Asterionella japonica)	Algae	SW	25	Cells	10000	1000	0.8	1250	Riley and Roth 1971
Algee Chlorella strain Algee Unable reviolecta Algee Successor Algee S	Silver	Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	8800	880	0.8	1100	Riley and Roth 1971
Age Duraliello prinofecto Age SW 25 Cells 900 900 0.8 1125 F Age (Punaliella vertoecos) Age SW 25 Cells 780 780 0.8 1125 Age (Punaliella vertoecos) Age SW 25 Cells 7100 1410 0.8 1753 Age (Ierrichnis homesces) Age SW 25 Cells 7000 1020 0.8 1753 Age (Ierrichnis i ongifilis) Age SW 25 Cells 1000 1100 1410 0.8 1753 Age (Micconons squemata) Age SW 25 Cells 1000 1020 0.8 1753 Age (Micconons squemata) Age SW 25 Cells 13700 1390 0.8 1753 Age (Micconons squemata) Alge SW 25 Cells 13700 1370 0.8 1753 Age (Micconons squemata) Alge SW 25 Cells 13700 1390 390 390 390 391 7753	Silver	Algae (Chlorella salina)	Algae	SW	25	Cells	4600	460	0.8	575	Riley and Roth 1971
Ager Unmicilal reviolecta) Ager SW 25 Cells 7800 780 <th< td=""><td>Silver</td><td>Algae (Dunaliella primolecta)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>0006</td><td>006</td><td>0.8</td><td>1125</td><td>Riley and Roth 1971</td></th<>	Silver	Algae (Dunaliella primolecta)	Algae	SW	25	Cells	0006	006	0.8	1125	Riley and Roth 1971
Ages <i>Utenischnis brunescens</i> Alges SW 25 Cella 14100 1410 0.8 1753 F Alges <i>Utenischnis virescens</i> Alges SW 25 Cella 3700 370 0.8 1753 1 Alges <i>Witcomans squamata</i> Alges SW 25 Cella 1700 170 0.8 1735 1 1 0.8 1735 1 1 1 0.8 1 1 0.8 1 1 0.8 1 1 0.8 1 1 0.8 1 1 0.8 1 1 1 0.8 1 <td>Silver</td> <td>Algae (Dunaliella tertiolecta)</td> <td>Algae</td> <td>SW</td> <td>25</td> <td>Cells</td> <td>7800</td> <td>780</td> <td>0.8</td> <td>975</td> <td>Riley and Roth 1971</td>	Silver	Algae (Dunaliella tertiolecta)	Algae	SW	25	Cells	7800	780	0.8	975	Riley and Roth 1971
Alge (Itensinativ ivrescens) Alger SW 25 Cells 3700 370 0.8 463 Alge (Itensinativ ivrescens) Alger SW 25 Cells 10000 1020 0.8 453 Alge (Vircumonas squamata) Alger SW 25 Cells 10000 1030 0.8 173 Alge (Vircumonas squamata) Alger SW 25 Cells 13700 1310 0.8 173 Alge (Vircumum) Alger SW 25 Cells 13700 1310 0.8 173 Alge (Vircumum) Alger SW 25 Cells 13700 1310 0.8 173 Alge (Vircumum) Alger SW 25 Cells 13700 1310 0.8 173 Alge (Vircumum) Alger SW 25 Cells 13700 1910 0.8 173 Alge (Vircumum) Alger SW 25 Cells 9700 9700 98 173 Alge (Vircumum) Alger SW 25 Cells <td< td=""><td>Silver</td><td>Algae Utemiselmis brunescens)</td><td>Algae</td><td>SW</td><td>25</td><td>Cells</td><td>14100</td><td>1410</td><td>0.8</td><td>1763</td><td>Riley and Roth 1971</td></td<>	Silver	Algae Utemiselmis brunescens)	Algae	SW	25	Cells	14100	1410	0.8	1763	Riley and Roth 1971
Algae Ulteromatix longifilis) Algae SW 25 Cells 10200 1020 0.8 1275 Algae (Micromonts squamata) Algae SW 25 Cells 4500 450 0.8 755 Algae (Micromonts squamata) Algae SW 25 Cells 4500 450 0.8 755 Algae (Micromonts squamata) Algae SW 25 Cells 15700 1713 10 Algae (Vistobalicus intern) Algae SW 25 Cells 15700 970 970 0.8 713 Algae (Fraudopedinella pyriformis) Algae SW 25 Cells 3800 380 0.8 173 Algae (Fraudopedinella pyriformis) Algae SW 25 Cells 12600 1260 0.8 173 Algae (Fraudopedinella pyriformis) Algae SW 25 Cells 3800 380 0.8 173 Algae (Fraudopedinella pyriformis) Fish FW FW 180 WB - 100 19 Blue gill (Feroastrui sterrathel	Silver	Algae (Hemiselmis virescens)	Algae	SW	25	Cells	3700	370	0.8	463	Riley and Roth 1971
Algre (<i>Micromonus squamata</i>) Algre SW 25 Cells 4500 450 450 0.8 563 1 Algre (<i>Micromonus squamata</i>) Algre SW 25 Cells 6200 620 0.8 775 1 Algre (<i>Micromonus squamata</i>) Algre SW 25 Cells 13700 13700 0.8 775 1 Algre (<i>Microbarchum tricomutum</i>) Algre SW 25 Cells 13700 13700 0.8 773 1 Algre (<i>Frauseints transhels</i>) Algre SW 25 Cells 3800 0.8 773 1	Silver	Algae (Heteromastix longifillis)	Algae	ΜS	25	Cells	10200	1020	0.8	1275	Riley and Roth 1971
Algae Wonochysis lutheri Algae SW 25 Cells 6200 620 0.8 773 Algae (0listhediscus luteus) Algae SW 25 Cells 13700 1370 0.8 773 1 Algae (0listhediscus luteus) Algae SW 25 Cells 13700 1370 0.8 773 1 Algae (Pstudopedinella pyriformis) Algae SW 25 Cells 9700 970 0.8 1713 1 Algae (Ferusainis terratedia) Algae SW 25 Cells 3800 380 0.8 173 1 Algae (Ferusainis terratedia) Algae SW 25 Cells 3800 380 0.8 173 1 Bluegill (Lepomis macrochirus) Fish FW 180 WB - 190 0.0 10 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Silver	Algae (Micromonas squamata)	Algae	ΝS	25	Cells	4500	450	0.8	563	Riley and Roth 1971
Algae (Olisthodiscus lureus)Algae SW25Cells1370013700.817131Algae (Olisthodiscus lureus)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)0.88251Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)0.88231Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)0.812131Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)0.812131Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)0.812131Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)1111Algae (Srichococcus bacillaris)Algae (Srichococcus bacillaris)111111Buegil (Leponis macrochirus)Fish FW180WB	Silver	Algae (Monochrysis lutheri)	Algae	ΜS	25	Cells	6200	620	0.8	775	Riley and Roth 1971
Algae (Phaeodacylum tricornuum) Algae SW 25 Cells 6600 660 0.8 825 1 Algae (Prevacint pyriformis) Algae SW 25 Cells 9700 9700 970 0.8 1213 1 Algae (Firtrastinis terrathet) Algae SW 25 Cells 3800 380 0.8 1715 1 Algae (Firtrastinis terrathet) Algae SW 25 Cells 12600 1260 0.8 1775 1	Silver	Algae (Olisthodiscus luteus)	Algae	ΜS	25	Cells	13700	1370	0.8	1713	Riley and Roth 1971
Algae (Pseudopedinella pyriformis) Algae SW 25 Cells 9700 970 0.8 1213 1 Algae (Frenzeimis terrathet) Algae SW 25 Cells 3800 380 0.8 475 1 Algae (Ferraseimis terrathet) Algae SW 25 Cells 12600 12600 0.8 1575 1 Bluegil (Lepomis macrochirus) Fish FW 180 WB 150 10 150 1 765	Silver	Algae (Phaeodactylum tricornutum)	Algae	SW	25	Cells	9600	660	0.8	825	Riley and Roth 1971
Algae Sirchococcus bacillaris) Algae SW 25 Cells 3800 380 0.8 475 Algae (Ferraseimis terrathet) Algae SW 25 Cells 12600 1260 0.8 1575 Bluegill (Lepomis macrochirus) Fish FW 180 WB - 150 10 15 Bluegill (Lepomis macrochirus) Fish FW 180 WB - 1500 100 150 Bluegill (Lepomis macrochirus) Fish FW 180 WB - 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1 11 1	Silver	Algae (Pseudopedinella pyriformis)	Algae	SW	25	Cells	9700	970	0.8	1213	Riley and Roth 1971
Algae (Terraseimis terrathet) Algae SW 25 Cells 12600 1260 0.8 1575 Bluegil (Lepomis macrochirus) Fish FW 180 WB 150 10 15 1 Bluegil (Lepomis macrochirus) Fish FW 180 WB 150 10 15 1 Bluegil (Lepomis macrochirus) Fish FW 180 WB 1500 10 15 1 11 1 1 1 1 1 1 11 1 11 1 11 1 11 1 1 1 1 1 1 1 1 1 1 1	Silver	Algae (Srichococcus bacillaris)	Algae	SW	25	Cells	3800	380	0.8	475	Riley and Roth 1971
Bluegil (Lepomic macrochirus) Fish FW 180 WB 150 10 15 1 Bluegil (Lepomic macrochirus) Fish FW 180 WB 1500 100 150 1	Silver	Algae (Tetraseimis tetrathele)	Algae	SW	25	Cells	12600	1260	0.8	1575	Riley and Roth 1971
Bluegil (Lepomic macrochirus) Fish FW 180 WB 15000 100 150 Largemouth bass (Micropterus salmoides) Fish FW 120 Muscle 11 11 11 1 11 11 11 1 11 11 <td< td=""><td>Silver</td><td>Bluegill (Lepomis macrochirus)</td><td>Fish</td><td>FW</td><td>180</td><td>WB</td><td>I</td><td>150</td><td>0</td><td>15</td><td>USEPA 1987b</td></td<>	Silver	Bluegill (Lepomis macrochirus)	Fish	FW	180	WB	I	150	0	15	USEPA 1987b
Largemouth bass (Micropierus salmoides) Fish FW 120 Muscle - 11 1 1 11 Largemouth bass (Micropierus salmoides) Fish FW 120 Muscle - 190 10 19 19 19 10 19 19 19 19 19 19 19 19 19 19 19 10 19 10 19 19 10 19 10 19 10 19 10 19 10 19 10<	Silver	Bluegill (Lepomis macrochirus)	Fish	FW	180	WB	!	15000	001	150	USEPA 1987b
Largemouth bass Wicropterus salmoides) Fish FW 120 Muscle - 190 10 19 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 7550 755 1 765 6 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 7750 775 5 155 6 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 10550 106 </td <td>Silver</td> <td>Largemouth bass (Micropterus salmoides)</td> <td>Fish</td> <td>FW</td> <td>120</td> <td>Muscle</td> <td>1</td> <td>=</td> <td>-</td> <td>=</td> <td>USEPA 1987b</td>	Silver	Largemouth bass (Micropterus salmoides)	Fish	FW	120	Muscle	1	=	-	=	USEPA 1987b
Blue mussel Myrilus edulis) Invert SW 630 Soft parts 7650 765 1 765 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 7750 775 5 155 65 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 10550 105 106 106 Blue mussel Myrilus edulis) Invert SW 630 Soft parts 10550 100 106 1	Silver	Largemouth bass (Micropterus salmoides)	Fish	FW	120	Muscle	I	190	10	19	USEPA 1987b
Blue mussel Myrilux edulis) Invert SW 630 Soft parts 7750 775 5 155 6 Blue mussel Myrilux edulis) Invert SW 630 Soft parts 10550 1055 10 106 0 Gastropod (Crepidula fornicata) Invert SW 730 WB 10800 109.93 98 7 Mayfly (Ephemerella grandis) Invert FW WB -35 1 Mayfly (Ephemerella grandis) Invert FW WB 240 1	Silver	Blue mussel (Mytilus edulis)	Invert	SW	630	Soft parts	7650	765	-	765	Calabrese et al. 1984
Blue mussel (Myrilus edulis) Invert SW 630 Soft parts 10550 1055 10 106 0 Gastropod (Crepidula fornicata) Invert SW 730 WB 10800 109.93 98 P Mayfly (Ephemerella grandis) Invert FW WB 35 1 Mayfly (Ephemerella grandis) Invert FW WB 240 1	Silver	Blue mussel (Myrilus edulis)	Invert	SW	630	Soft parts	7750	775	ŝ	155	Calabrese et al. 1984
Gastropod (Crepidula fornicata) Invert SW 730 WB 10800 109.93 98 1 Mayfly (Ephemerella grandis) Invert FW WB -35 1 Mayfly (Ephemerella grandis) Invert FW WB 240 1	Silver	Blue mussel (Mytilus edulis)	Invert	SW	630	Soft parts	10550	1055	10	106	Calabrese et al. 1984
Mayfly (Ephemerella grandis) Invert FW WB 35 1 Mayfly (Ephemerella grandis) Invert FW WB 240 1	Silver	Gastropod (Crepidula fornicata)	Invert	SW	730	WB	ł	10800	109.93	98	Nelson et al. 1983
Mayfly (Ephemerella grandis) Invert FW WB 240 I	Silver	Mayfly (Ephemerella grandis)	Invert	FW		WB	I	ł	I	35	USEPA 1980
	Silver	Mayfly (Ephemerella grandis)	Invert	FW		WB	I	I	I	240	USEPA 1980

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

November 5. 1999

AR 044673

	Organism	Water	Duration		Tissue	Tissue	Water		
Metal/Metalloid Species	Type	Type	(days)	Tissue	(hg/kg-dry)	-	(µg/L)	BCF	Reference
Stonefly (Claasenia sabulosa)	Invert	ΡW		WR	I	I	I	51	11SEPA 1980
Stonefly (Pteronarcys californica)	Invert	FW		WB	ł	I	I	21	USEPA 1980
Stonefly (Pteronarcys californica)	Invert	FW		WB	ł	1	ł	170	USEPA 1980
Stonefly (Pteronarcys californica)	Invert	FW		WB	ł	ł	ł	79	USEPA 1980
Atlantic salmon (Salmo salar)	Fish	FW	>83	Gills	I	25597	17.9	1430	Zitco et al. 1975
Atlantic salmon (Salmo salar)	Fish	FW	> 83	Liver		3866	17.9	216	Zitco et al. 1975
Atlantic salmon (Salmo salar)	Fish	FW	>83	Muscle	1	2327	17.9	130	Zitco et al. 1975
Bluegill (Lepomis macrochirus)	Fish	FW	28	WB	ł	2720	80	34	Barrows et al. 1980
Blue mussel (Mytilus edulis)	Invert	SW	4	Soft parts	2170	217	50.5	4.29703	Zitko and Carson 1975
Blue mussel (Myrilus edulis)	Invert	SW	40	Soft parts	5200	520	101.5	5.123153	Zitko and Carson 1975
Soft-shell clam (Mya arenaria)	Invert	SW	88	Soft parts	3780	378	47.2	8.008475	Zitko and Carson 1975
Soft-shell clam (Mya arenaria)	Invert	SW	88	Soft parts	10780	1078	103.6	10.40541	Zitko and Carson 1975
Tin (inorganic) Algae (Asterionella japonica)	Algae	SW	25	Cells	35000	3500	01	350	Riley and Roth 1971
Tin (inorganic) Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	29500	2950	10	295	Riley and Roth 1971
Tin (inorganic) Algae (Dunaliella primolecta)	Algae	ΜS	25	Cells	34000	3400	10	340	Riley and Roth 1971
Tin (inorganic) Algae (Dunaliella tertiolecta)	Algae	ΝS	25	Cells	17500	1750	01	175	Riley and Roth 1971
Tin (inorganic) Algae (Hemiselmis brunescens)	Algae	SW	25	Cells	45500	4550	01	455	Riley and Roth 1971
Tin (inorganic) Algae (Hemiselmis virescens)	Algae	SW	25	Cells	28000	2800	01	280	Riley and Roth 1971
Tin (inorganic) Algae (Heteromastix longifillis)	Algae	SW	25	Cells	00096	0096	01	960	Riley and Roth 1971
Tin (inorganic) Algae (Micromonas squamata)	Algae	SW	25	Celis	22400	2240	01	224	Riley and Roth 1971
Tin (inorganic) Algae (Monochrysis lutheri)	Algae	SW	25	Cells	49500	4950	10	495	Riley and Roth 1971
Tin (inorganic) Algae (Phaeodactylum tricornutum)	Algae	SW	25	Cells	101000	10100	10	1010	Riley and Roth 1971
Tin (inorganic) Algae (Pseudopedinella pyriformis)	Algae	SW	25	Cells	00011	1100	01	110	Riley and Roth 1971
Tin (inorganic) Algae (Stichococcus bacillaris)	Algae	SW	25	Cells	34500	3450	0	345	Riley and Roth 1971
Algae (Chlamydomonas sp.)	Algae	SW	25	Cells	1200	120	20	9	Riley and Roth 1971
Algae (Chlorella salina)	Algae	SW	25	Cells	3700	370	20	61	Riley and Roth 1971
Algae (Dunaliella primolecta)	Algae	SW	25	Cells	2400	240	20	12	Riley and Roth 1971
Algae (Dunaliella tertiolecta)	Algae	SW	25	Ceils	2900	290	20	15	Riley and Roth 1971
Algae (Micromonas squamata)	Algae	SW	25	Cells	5700	570	20	29	Riley and Roth 1971
Algae (Monochrysis lutheri)	Algae	SW	25	Cells	3100	310	20	16	Riley and Roth 1971
Algae (Stichococcus bacillaris)	Algae	SW	25	Cells	2400	240	20	12	Riley and Roth 1971
Algae (Asterionella japonica)	Algae	ΜS	25	Cells	115000	11500	150	F	Riley and Roth 1971
Algae (Chlamydomonas sp.)	Algae	ΜS	25	Cells	116000	11600	150	11	Riley and Roth 1971
Algae (Chlorella salina)	Algae	ΝS	25	Cells	301000	30100	150	201	Riley and Roth 1971
Algae (Dunaliella primolecta)	Algae	SW	25	Cells	405000	40500	150	270	Riley and Roth 1971
Algae (Dunaliella tertiolecta)	Algae	ΜS	25	Cells	285000	28500	150	190	Riley and Roth 1971
Algae (Hemiselmis brunescens)	Algae	ΜS	25	Cells	480000	48000	150	320	Riley and Roth 1971
Algae (Hemiselmis virescens)	Algae	ΜS	25	Cells	259000	25900	150	173	Riley and Roth 1971
Algae Ufeteromastix longifillis)	Algae	SW	25	Cells	325000	32500	150	217	Riley and Roth 1971
Algae (Micromonas squamata)	Algae	SW	25	Cells	105000	10500	150	70	Riley and Roth 1971
Algae (Micromonas squamata)	Algae	SW	25	Cells		105000		10500	10500 150

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

Metalloid Zinc Zinc Zinc Zinc Zinc Bi Bi Zinc Bi Bi Zinc Zinc Zinc Zinc Zinc Zinc Zinc Zin	Species Algae (Monochrysis lutheri) Algae (Monochrysis lutheri) Algae (Plaeodacylum tricornutum) Algae (Praeodacylum tricornutum) Algae (Tetraseimis tetrathele) Brown macroalga (Accophylium nodosum) Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Diatom (Dipylum brightwellii) Diatom (Dipylum brightwellii)	Type Algac Algac Algac Algac Algac Algac Algac Algac Algac Algac	Type SW SW	(days)	Tissue	(µg/kg-dry)	(µg/kg-dry) (µg/kg-wet)	(µg/L)	BCF 107	Reference
	Ngae Monochrysis lutheri) Ngae (Nosthodiscus luteus) Ngae (Phaeodacrylum tricornutum) Ngae (Phaeodacrylum tricornutum) Ngae (Feraseimis tetratheli) Ngae (Tetraseimis tetratheli) Ngar (Tetraseimis tetratheli) Ngar (Tetraseimis tetratheli) Ngar (Tetraseimis tetratheli) Ngar (Dirylum brightwelli) Ngatom (Dirylum brightwelli) Natom (Dirylum brightwelli)	A ligae A ligae A ligae A ligae A ligae A ligae A ligae A ligae A ligae	8 W S		Calle			160	107	
	<pre>Algae (Olisthodiscus luteus) Algae (Phaeodacrylum tricornutum) Algae (Pseudopedinella pyriformis) Algae (Stichococcus bacillaris) Algae (Tetraseimis tetrathelt) Algae (Tetraseimis tetrathelt) Brown mactoalga (Fucus serratus) Brown mactoalga (Fucus serratus) Brown mactoalga (Fucus serratus) Brown mactoalga (Fucus serratus) Diatom (Ditylum brightwellii) Diatom (Ditylum terriolecta)</pre>	A ligate A ligate A ligate A ligate A ligate A ligate A ligate A ligate	SW	25		1 KNNN			101	
	Algae (Phaeodacrylum tricorrutum) Algae (Pseudopedinella pyriformis) Algae (Stichococcus bacillaris) Algae (Tetraseimis tetrathele) Algae (Tetraseimis tetrathele) Algae (Tetraseiga (Ascophylium nodosum) Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii)	A lease A lease A lease A lease A lease A lease A lease A lease) X	Cells	75000	7500	0	5	Kiley and Koth 19/1
	Algae U'seudopedinella pyriformis) Algae (Sichococcus bacillaris) Algae (Tetraseimis tetrathele) Algae (Tetraseimis tetrathele) Alown mactoalga (Ascophylium nodosum) Brown mactoalga (Fucus serratus) Brown mactoalga (Fucus serratus) Brown mactoalga (Fucus serratus) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii)	A lease A lease A lease A lease A lease A lease A lease	ΜS) X	Celle			001	2 2	Kiley and Koth 19/1
	(Igae (Stichococcus bacillaris) (Igae (Terraseimis tetrathele) (Igae (Terraseimis tetrathele) Inown mactoalga (Accophylium nodosum) Inown mactoalga (Fucus serratus) Inown mactoalga (Fucus serratus) Inown mactoalga (Fucus serratus) Inotom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Ilgae (Dundiella terriolecta)	A ligate A ligate A ligate A ligate A ligate A ligate A ligate	m o	1 X	5.H-C	000170	00076	001	117	Kiley and Koth 19/1
	Age (Tetraseinis tetrathetk) Nown macroalga (Accophylium nodosum) Nown macroalga (Fucus serratus) Nown macroalga (Fucus serratus) Natom (Dinylum brightwellii) Natom (Dinylum brightwellii) Natom (Dinylum brightwellii) Natom (Dinylum brightwellii) Natom (Dinylum brightwellii) Natom (Dinylum brightwellii)	Algae Algae Algae Algae Algae Algae Algae		3 2		243000	24300	001	162	Riley and Roth 1971
	rugae v errusermis terrunete) Brown macroalga (Accophylium nodosum) Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii)	Algae Algae Algae Algae Algae Algae	A	3	Cells	251000	25100	150	167	Riley and Roth 1971
	stown macroalga Ascophylium nodosum) Rown macroalga (Fucus serratus) Rown macroalga (Fucus serratus) Rown macroalga (Fucus serratus) Diatom (Ditylum brightwellit) Diatom (Ditylum brightwellit) Diatom (Ditylum brightwellit) Diatom (Ditylum brightwellit) Diatom (Ditylum brightwellit) Lgae (Dundiella tertiolecca)	Algae Algae Algae Algae Algae	SW	25	Cells	410000	41000	150	273	Riley and Roth 1971
	Rown macroalga Gucus serratus) Rown macroalga Gucus serratus) Rown macroalga Gucus serratus) Diatom Witylum brightwellii) Diatom Witylum brightwellii) Diatom Witylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum terriolecta)	Algae Algae Algae Algae Algae	SW	Field	WB	I	ł	11.3	1318	USEPA 1987c
	Brown macroalga (Fucus serratus) Brown macroalga (Fucus serratus) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum terriolecta)	Algae Algae Algae Algae	SW	140	WB	j	ł	9.6	10768	LISEPA 1987
	trown mactoalga (Fucus serratus) liatom (Diŋylum brightwellii) Diatom (Diŋylum brightwellii) Diatom (Diŋlum brightwellii) Diatom (Diŋylum brightwellii) Ligae (Dunditella terriolecca)	Algae Algae Algae Algae	ΜS	Field	WB	ļ	ł	5 11-10 S		1001 V 1001
	iatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Diatom (Ditylum brightwellii) Agae (Dunditella terriolecca)	Algae Algae Algae	Mo No	Field]	ł	6.11-12.0	6707	USERA 198/C
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	Jatom (Juyum brighwellii) Diatom (Diyum brighwellii) Diatom (Diyum brighwellii) Diatom (Diyum brighwellii) Agae (Dundiella tertiolecia)	Algae Algae	SW	4	Cells	120000	12000	25	480.0	Canterford et al. 1978
	ilatom (Ditylum brighrwellii) Diatom (Ditylum brighrwellii) Diatom (Ditylum brighrwellii) Ugae (Dundiella terriolecia)	Alme	SW	4	Cells	100000	10000	80	200.0	Canterford et al. 1978
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	iatom (Diyylum brightwellii) Igae (Dunaliella tertiolecta)	Algae	SW	14	Cells	170000	17000	951	113.2	
	Agae (Dunaliella tertiolecta)	Alose	M S		Colle	1 50000	1 6000	001		
		nigat.		± ;	Cells	mmci	nnci	700	0.67	Canterford et al. 1978
• -		Algae	SW	0.5	WB	I	I	7.2-98000	10000	USEPA 1987c
	Diatom (<i>I halassiosira pseudonana</i>)	Algae	SW	0.5	WB	ł	1	7.2-98000	12000	USEPA 1987c
	Atlantic salmon (Salmo salar)	Fish	FW	80	WB	i	28000	2	14000	Farmer et al 1979
	Atlantic salmon (Sa <i>lmo salar</i>)	Fish	FW	80	WB	ł	34000	320	106.25	Farmer et al 1070
Zinc At	Atlantic salmon (Salmo salar)	Fish	FW	80	WB	I	37000	995	ek.	Farmer at at 1070
Zinc At	Atlantic salmon (Salmo salar)	Fish	FW	80	WB	I	42000	CPL	3 5	Farmer of al 1070
Zinc Fl	Flagfish Vordanella Jloridae)	Fish	FW	100	WB	120000	00006		2 2 2 2 2	
Zinc Fl	Flagfish (Jordanella floridae)	Fieh	ΕM	001	aw	000021	000017		1.000	
	Flarfish (lordanella floridae)	r 131 Fish	:	001		000021	00007	4 . 1	0.000	Spenar et al. 19/8
			× 1	001	AB	320000	64000	73.4	871.9	Spehar et al. 1978
	laglish Vordanella Jonidae)	Fish	FW	100	WB	270000	54000	105	514.3	Spehar et al. 1978
	r lagtish Vordanella Jloridae)	Fish	FW	100	WB	250000	5000	127	393.7	Spehar et al. 1978
	riaglish Vordanella floridae)	Fish	FW	100	WB	270000	54000	139	388.5	Spehar et al. 1978
-	Guppy (Poecilia reticulata)	Fish	FW	134	WB	444000	88800	166	535	Pierson 1981
-	Guppy (Poecilia reticulata)	Fish	FW	134	WB	430000	86000	180	478	Pierson 1981
_	Guppy (Poecilia reticulata)	Fish	FW	134	WB	828000	165600	336	401	Pierson 1981
Zinc Gu	Guppy (Poecilia reticulata)	Fish	FW	134	WB	1540000	308000	310	066	Piercon 1081
Zinc Gu	Guppy (Poecilia reticulata)	Fish	FW	134	WB	155000	310000	503	ŝ	Diamon 1081
Zinc Gu	Guppy (Poecilia reticulata)	Fish	FW	134	WB	1420000	284000	609	AKK	Diamon 1081
Zinc M1	Mummichog (Fundulus heteroclitus)	Fish	MS	36	aw B	000106	00007	10		Court and Writte 1984
Zinc Mi	Mummichoe (Fundulus heteroclitus)	Eich	10	2		000107	00704	017	1.16	Sauci and watabe 1964
	Mummichov (Fundulus heteroclitus)	1.1		2		000707		010	7.20	Saucr and Walabe 1984
-		LISN .	Ň	90	WB	413000	82600	7880	10.5	Sauer and Watabe 1984
	Ampuipod Autorchestes compressa)	Invert	SW	28	WB	125000	25000	58	431.0	Ahsanulla and Williams 1991
	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	130000	26000	82	317.1	Ahsanulta and Williams [99]
-	Amphipod (Allorchestes compressa)	Invert	SW	28	WB	145000	29000	131	221.4	Ahsanulla and Williams 199
Zinc An	Amphipod (Allorchestes compressa)	Invert	ΜS	28	WB	160000	32000	140	2286	Aheamilta and Williams 1001

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds

November 5, 1999

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renwinkie (Liliozina oonwala) Invert SW Soft parts	2620000 1000	2620 Timmermans et al. 1992
Shirmp (Pandalus montogut) Invert SW 14 WB 70000 Soft-shell clam (Mya arenaria) Invert SW 50 Soft parts Zebra mussel (Dreissena polymorpha) Invert FW 70 Soft parts 100000 Zebra mussel (Dreissena polymorpha) Invert FW 70 Soft parts 100000	=	670 USEPA 1987c
Soft-shell clam (Mya arenaria) Invert SW 50 Soft parts I Zebra mussel (Dreissena polymorpha) Invert FW 70 Soft parts 100000 I Zebra mussel (Dreissena polymorpha) Invert FW 70 Soft parts 100000 I	14000 65	
Zebra mussel (Dreissena polymorpha) Invert F.W 70 Soft parts 100000 I Zebra mussel (Dreissena polymorpha) Invert F.W 70 Soft mare 100000	•••	
Zebra mussel (Dreissena polymorpha) Invert F.W 70 Soft marte Innova		~
Invert FW 70 Soft parts 20000		
Soft parts 200000	20000 101	
Soft marts Tomon		

FW = Freshwater SW = Saltwater WB = Whole body

November 5, 1999

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^{--- =} Not reported

Critical Review of the Use of Bioaccumulation Potential for Hazard Classification of Metals and Metal Compounds